TEXT-BOOK

OF

EGYPTIAN AGRICULTURE

MINISTRY OF EDUCATION, EGYPT.

TEXT-BOOK

EGYPTIAN AGRICULTURE,

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VOL. I.

CAIRO

NATIONAL PRINTING DEPARTMENT

1908.

CONTENTS.

Vol. I.

Vol. II.

TABLE OF ILLUSTRATIONS.

PREFACE.

THIS Text-Book is intended primarily for the use of Egyptian students of Agriculture. As, however, it constitutes the first attempt yet made at a more or less complete account of the Agriculture of Egypt, it is hoped that it may prove of interest to others engaged in tropical Agriculture. As will be seen from the list of contributors most of them are, or have been, engaged in actually teaching Agriculture at the School of Agriculture, Ghizeh, while the rest have all assisted at the examination of the students of the School in this subject.

An acknowledgment is due to the help rendered by Dr. Mackenzie, formerly Principal of the Schools of Agriculture and of Engineering, who, up to the time of his retirement *in June 1907, had acted as one of the Editors.*

THE EDITORS.

EGYPTIAN AGRICULTURE

CHAPTER I.

ATMOSPHERE AND CLIMATE IN RELATION TO AGRICULTURE.

IN its relation to agriculture the atmosphere may best be considered from two points of view: the chemical and the physical. The composition of dry air is very constant and for practical purposes may be taken at:—

Oxygen............	20·90	per cent. by volume.
Nitrogen...........	79·06	„ „ „
Carbon Dioxide...	0·04	„ „ „

The atmosphere, however, contains other substances of which the most important is water vapour, present in varying quantities—1·40 per cent. on the average—dependent largely upon the temperature. The water vapour will be best considered under the physical conditions of the atmosphere.

The nitrogen gas is not directly of any use but indirectly, by diluting the oxygen gas, it renders possible the existence of the present forms of life. The oxygen and carbon dioxide are the two components of the air which are of vital importance: without either of them all life would be impossible. Plants and animals must constantly breathe or death quickly ensues. Breathing consists in

oxygen gas being taken into the living body where it is used to unite with other substances for the production of heat and vital energy. Life is an active condition and without the production of energy, activity and life are impossible. In the body, energy is only produced by the combustion of the food materials. With few exceptions, the combustion taking place in the animal or plant body consists in the oxidation of the organic substances of the food.

It is of the greatest importance that the agriculturist should understand the ordinary phenomenon of burning or combustion. Combustion is the union of oxygen with some other substance. When oxygen unites with iron, "rust" is formed and heat is given out; when it unites with the carbon in wood, carbon dioxide and heat result from the combination. Combustion or oxidation may be rapid or slow. Rapid combustion produces much heat in a short time which results in a high temperature with perhaps the production of light, whereas slow combustion may be invisible. If a piece of sugar or starch is burnt in the air or oxygen a high temperature is produced. If an animal or plant consumes an equal quantity of sugar or starch, the same amount of heat is produced in its oxidation in the living body, but the combustion is slower and takes place at a lower temperature. In the animal or plant, sugar and starch are burnt at a little over the body temperature whereas in the air a hot flame must be applied before combustion will begin. This power to combust or oxidize bodies at a low temperature is one of the attributes of life. From combustion, heat is produced; and this heat may be used to drive engines and do other

work, or it may be used in the living body to produce the energy necessary to pump the blood, move the muscles, or build up new tissues. The heat produced in decaying vegetable matter is another manifestation of slow combustion. Sometimes, in manure containing very much vegetable matter, so much heat is produced by slow combustion that the heap is able to break into fire or rapid combustion. Enough has been said to show that the heat used to drive the engine, the heat supporting the internal life of animals and plants, and the heat arising from decaying vegetable matter, is produced in each case from a similar cause, namely the oxidation of organic matter. In such cases therefore oxygen is necessary for the production of heat and vital energy, and carbon dioxide is a product resulting from the oxidation of organic substances.

Animals and plants exhale carbon dioxide and fires give off this gas, yet, except in enclosed spaces, it never becomes appreciably greater in quantity in the atmosphere. This is because the carbon dioxide is a plant food and is constantly being extracted from the air to build up the plant body. When air enters the plant, the carbon dioxide is split up, the oxygen going back to the atmosphere while the carbon is used to build up the solid plant body. What plants take from the air—*i. e.* carbon dioxide—is returned by breathing, burning and decay: what animals take from the air—oxygen—is returned by plants. The materials which plants take from the soil, are returned again in the dead bodies and excreta of animals and plants, and the residue of fires. Animals and plants form one cycle capable of living and taking the materials for

life without destroying or lessening the substances for the production of new life.

In the atmosphere there are minute quantities of combined nitrogen in the form of ammonia, nitric and nitrous compounds, and organic matter, which ultimately fall on the earth in the waters of rain and dew. These substances are important plant foods because of the nitrogen contained in them, but the quantity received from the air in this way is small. It varies in different places and years. In England, at Rothamsted, it has been found to amount to about 4·4 rotls of nitrogen per feddan, per annum, consisting of 2·4 rotls as ammonia compounds, 1 rotl as nitrates and nitrites, and 1 rotl as organic nitrogen. In Egypt the rainfall is small, amounting to about 3·5 centimetres per annum in the neighbourhood of Cairo, and the gain of nitrogen to the soil by means of the rain is therefore also small. Rain water collected at Ghizeh during the winter of 1900-1901, amounting to 3·625 centimetres, was found to contain nitrogen equivalent to 94 grams per feddan (a little more than one fifth of a rotl) made up of 57·6 grams as compounds of ammonia, 17·4 grams as nitrates and nitrites, and 19 grams as organic nitrogen. This quantity is so small that it may be altogether neglected when considering the sources of soil nitrogen. Dust and smoke in the atmosphere are very hurtful to plants when they occur in any considerable quantity.

Climate in relation to agriculture.—In this connection the physical conditions of the atmosphere—light, temper-

ature, humidity and winds—affecting plants and animals will be briefly considered. It will be advisable, in the first place, to say a word as to the effect vegetation has on the climate. A covering of vegetation protects the soil from the direct rays of the sun and tends to decrease surface evaporation: it lowers the temperature while at the same time it increases the moisture in the air. It must be noticed that the total water removed from a cultivated soil by surface evaporation and plant transpiration is much greater than that removed from bare land. The effect which forest would have on the climate of Egypt is a subject admitting of much speculation. The air of a wood is slightly moister and colder than in the open plain; but there is no proof that woods increase the total rainfall. In any case it is highly improbable that, in such a rich agricultural country as Egypt, the planting of trees will ever be so extensive as to make any appreciable difference in the climate.

SHADE TEMPERATURE RECORDS 1884-1905.

(Near Cairo).

MONTH	MEAN TEMPERATURE	ABSOLUTE MAXIMUM	ABSOLUTE MINIMUM
January	12·12	26·6	−0·7
February	14·28	35·3	1·2
March...	16·75	41·2	3·2
April	20·63	42·6	5·7
May	24·42	44·2	9·0
June	27·00	45·2	12·3
July	28·14	44·3	16·0
August	27·43	41·6	15·5
September	25·11	40·6	13·0
October	23·04	42·1	12·0
November	17·97	33·6	3·5
December	14·08	29·4	1·0

The conditions of temperature affecting agriculture.—Extremes of heat and cold are equally active in bringing the life of plants to a standstill. As the temperature reaches an optimum for each plant, the plant is able to absorb more food and is better able to utilise that food for the purposes of life. The buds of trees only swell in spring when the surroundings are at a certain temperature. In the germination of seed, heat is of the greatest importance, as unless it is raised to a certain temperature the young embryo is unable to break into activity. In cold weather seeds germinate slowly and in consequence are in danger of decaying or of being destroyed by pests. Excessive heat hinders or stops the growth of plants. Late sown cereals are often killed or prematurely ripened by the hot summer weather before the grain is fully developed. On the other hand, it is only in the south of Egypt that the sugar-cane finds a sufficiency of heat to enable it to bring forth seeds. Crops vary in their demands for heat and it is therefore necessary to sow different crops at different seasons. Increased temperature of the soil increases the activity of all living bodies in the soil and at the same time quickens the chemical changes in the soil. In hay-making a high temperature is necessary as the green crop, if not rapidly dried, quickly begins to ferment.

Animals are able to withstand great differences in atmospheric temperature but sudden changes have a very detrimental effect on the animal system. The heat of summer causes great perspiration and consequent loss of heat to the animal body as well as exercising a bad effect on the nervous system. When the temperature approaches

zero, plants are subject to an attack of frost. With most plants, the colds occurring in Egypt are insufficient to do more than put a temporary stop to growth; but even here such crops as potatoes and tomatoes are often frosted. If a frosted plant is very slowly heated, the cell is able to take up water, and quickly recovers from its frosting. When quickly heated by the direct rays of the sun, the water is evaporated very rapidly and the frosted plant soon dies. Hence plants which are protected from the early rising sun or plants which have just been watered, seldom suffer from the cold. Cold weather in autumn often prevents the full ripening of the cotton crop, and frost causes damage to the sugar-cane by changing the crystallisable cane sugar into non-crystallisable sugars. While the growth of a crop depends upon certain limits of temperature, the full ripening of the crop further depends upon the crop growing a certain number of days at a certain temperature. If the number of days between the sowing and ripening of a crop is multiplied by the average temperature prevailing during that time, the result is the day-degree units of heat required for the ripening of the crop. The number of day-degree units required by any particular crop is fairly constant. Thus berseem sown on October 13th gave a crop of 10·5 tons in 48 days with an average temperature of 23°·7 C., and a crop sown on November 12th gave 10·6 tons after 74 days of an average temperature of 14°·3 C. The first crop took a much shorter time to mature, but received just about the same day-degree units of heat, namely 1037 against 1065 units.*

* *This method of measuring the heat received only applies if the maximum and minimum temperatures, of which an average is taken, are not too far apart.*—EDS.

ATMOSPHERIC MOISTURE (ABBASSIA OBSERVATORY).

MONTH	RATE OF EVAPORATION OF WATER Average for 17 years 1887-1903	HUMIDITY Average 1884-1905	Grams of water vapour per cubic meter of air at the average Temperature and Humidity.
	cms.	per cent.	grams.
January	5·64	68	7·19
February	6·93	63	7·53
March	11·96	59	8·46
April	14·73	52	9·44
May...	19·70	48	10·34
June	20·65	49	12·49
July	19·97	52	14·01
August	17·54	58	14·80
September	12·90	65	14·83
October	10·97	67	13·65
November	7·22	68	10·36
December	5·92	69	8·25
TOTAL ...	154·13		

For curves showing the Average Temperature, the Average Rate of Evaporation, and the Average Humidity, see Appendix.

The rate of evaporation as determined at the Abbassia Observatory has been decreasing year by year, probably due to more accurate measurements in recent years. From May 1901 to April 1902, the evaporation as determined at Abbassia amounted to 138·37 cms. This was determined in the shade, but an experiment at Ghizeh, by estimating the evaporation from a tank one metre deep and one square metre in area sunk into the ground, gave

a total evaporation for the same period of 198.70 cms. when exposed to wind and sun. (See Appendix).

Moisture occurs in the atmosphere either in the form of water vapour or minute drops. The moisture in the air is derived from the water which is evaporated from the earth's surface and from the water vapour given off from animals and plants. Moisture, as vapour in the atmosphere is invisible and the amount of vapour which may exist in the atmosphere depends upon the temperature. Thus 1 cubic metre of air may contain at 0° C. 4·871 grams of invisible water vapour, whereas at 10° C. it may contain 9·362 grams, at 20° C. 17·157 grams, at 30° C. 30·095 grams, and at 40° C. 50·70 grams. If the air contains a sufficient quantity of water vapour, and the temperature falls, the vapour in excess of what the air can contain at the lower temperature is condensed into small drops forming clouds, fog, snow, rain, or dew. The moisture in the atmosphere exerts great influence on animal and plant life. Too much or too little moisture is equally detrimental to the life and growth of plants. A dry atmosphere causes excessive plant transpiration and evaporation, and crops and soil require more irrigation. Generally it is advantageous to have a dry atmosphere when crops are ripening, but in the early stages of growth, if the temperature is fairly high, a fair amount of moisture facilitates the growth of the plants. In Egypt, crops are practically entirely dependent upon irrigation for their water supply, and the Nile obtains its water from the rains falling at its sources. So far as agriculture is concerned the rainfall of Egypt is of little importance.

AVERAGE RAINFALL IN CENTIMETRES PER ANNUM.

Alexandria	22·25	Average of 15 years
Port Said	7·38	.. .. 5 ..
Cairo...	3·28	.. .. 19 ..
Assiut	0	
Aswan	0	

Cloudy days are usually hot and damp because there is much moisture and the clouds prevent the heat from rising into the atmosphere. Dew may be formed at night when the damp air comes into contact with cold surfaces, as the leaves of plants. In Egypt the dew is more important than the rain. Dew often influences agricultural operations: thus over-ripe crops are cut in the dewy mornings: the norag can only work in the absence of dew: berseem covered with dew may not, with safety, be grazed by animals.

In moister climates crops develop greater leaf surface, the soil is more generally covered with vegetation and, as a general rule, vegetables and fruits attain better quality. Rain during the flowering season of fruit trees and crops, prevents fertilisation of the flowers and the production of fruit.

The light and heat derived from the rays of the sun are all important for the support of life. Many of the smaller plants are unable to grow or exist in bright sunlight. This is particularly the case with bacteria, and it is thanks to the light of the sun, that animals are able to

exist in spite of the prevalence of all kinds of disease bacteria. It is worthy of note that most of the insects attacking crops only fly and deposit their eggs at night, while very often the "worms" only feed during the dark hours of the night. Sunlight and heat are the only sources of energy available for carrying on life. The sun's rays supply the energy for plant growth, the energy for the evaporation of water and formation of rains, and supplied the energy which lies hidden in coal. It has been already noticed that when combustion—the union of oxygen with some other body—takes place, heat is produced; and the converse is true, that when oxygen is separated from some other body, energy is necessary. It was pointed out that the plant takes carbon dioxide from the air and splits it up, retaining the carbon to build up its body. The source of energy for this separation of oxygen is the sun's rays. Without this source of energy plants could not build up their bodies, and life could not exist. Too much light rather retards plant growth, and consequently at noon many plants "close up" and have a period of rest. Indirectly, light increases transpiration and the rate of the absorption of plant foods. The rays of light falling on the stem strengthen it, and plant stems which receive little light are weak and liable to be "laid." Thus when wheat or barley is sown very thickly, the lower parts of the stems are unable to obtain sufficient light to strengthen their tissues, and the whole crop often lies down. With forage crops, flax, lettuce, celery, etc., tender vegetation is obtained by sowing thickly or otherwise protecting the stems from the sun. Weeds are unable

to exist under thickly planted crops. Seed crops should be sown thinly so as to allow of the fullest formation of the seed.

Light breezes are usually conducive to health and vigour of life. Through shaking the leaves of plants, the breeze ensures a fresh supply of air from which the plant can abstract its food materials. By ventilation or the gentle circulation of air, animals are enabled to live in closed houses without suffering from the carbon dioxide which they exhale. Wind is also serviceable in bringing about the fertilisation of plants. Unfortunately it also fertilises and spreads the seeds of weeds. Further, it distributes the "seeds" of plant diseases. Hot, dry winds, causing excessive evaporation, are exhausting to both animals and plants. Strong winds do more or less damage in detaching the seeds from the plants and thereby decreasing the yield of the crop. When strong winds are blowing, great care is necessary in the watering of the cereal and maize crops; the water loosens the soil and plant roots and the wind "lays" the crop. The sand carried by strong winds injures the plants by cutting into their tissues damaging the plant and allowing of the easy entrance of disease germs.

CHAPTER II.

THE SOIL.

The soil is that part of the earth's surface into which plants send their roots in order to obtain foothold and nourishment. Geologically, soil is a recent rock consisting of the products of the "weathering" of older rocks, and mixed with decomposed animal and vegetable matter.

A "weathering agent" is something which, by physical or chemical action, aids in the decomposition of mineral and organic matter. Besides desintegrating the hard rocks to make soil, the weathering agents are ever acting on the soil particles, rendering them soluble and available for the feeding of plants. Since the weathering agents make the plant food available, it is necessary to enumerate a few of the most important. Water is one of the most powerful, and in addition, its presence is often a necessary condition for the action of other agents of decomposition. It decomposes by its power of dissolving substances and acts mechanically by friction when in motion. In the soil, water usually contains acids and salts in dilute solution which increase the weathering power of soil water for mineral and organic matter. Owing to the absence of rain in Egypt, weathering agents have less activity here than elsewhere, except where the mineral and organic matters come under the influence of infiltration or irrigation water. The Nile acts even a better part than that

of a weathering agent, for it collects the products of the weathering of rocks in its catchment area and brings them down in suspension as Nile mud.

Air, or more properly the oxygen of the air, is an agent which is constantly decomposing mineral and organic matter. It oxidizes many substances with which it is in contact but, as a weathering agent, its full effect is only utilised through the medium of living bodies. In the soil it supplies the small organisms with oxygen and these use it to decompose a great variety of bodies. The great importance of these organisms will be brought forward when considering the biological properties of the soils.

Variations in temperature, causing alternate expansion and contraction, contribute to the decomposition of rock material.

Cultivation, by exposing the soil to the action of the atmosphere, indirectly assists in the weathering of the soil particles and the preparation of plant food. When the weathering agents are decomposing the hard rock surface of the earth to form new soil, and when they are acting on and further decomposing the particles of the existing soil, they are preparing plant food and assisting the farmer.

In Egypt, except on irrigated lands, the weathering agents have only a feeble action, and it is fortunate that the supply of new soil is independent of that produced from the hard rocks of the country. The soil is practically all *alluvial soil*, and the particles of which it is composed have been carried by water to their present position. In the upper reaches of the Nile valley, the rain and other

weathering agents are continually breaking off little particles from the hard rocks. Many of these lie where they were dislodged and form the soil of the district: the rest of these particles are washed by the rain into the rivers, and coming down the Nile in a state of suspension, are ultimately deposited on the land and give a new supply of soil. The quantity of matter carried in suspension depends upon the velocity of the current and the size of the individual particles. When the flood water is allowed into the basins of Upper Egypt, the current practically ceases, and the suspended particles are deposited on the surface of the land. The clear water is run off and the soil is left with a layer of new soil or Nile mud on its surface. The coarser particles, largely sand, are first deposited, whilst the fine clay is carried to the greatest distance from the inlet of the basin and is deposited more slowly. Hence we find that the soil near to the place of entry of flood water into the basin is usually "lighter" in character, and forms the "Erd Asfar"; whereas the soil formed by the deposition of the fine clay gives us the "heavy" "Erd Iswud." The same process goes on where the land is under perennial irrigation, but much more slowly, as the water contains less matter in suspension and is not applied in such quantity. In addition to decomposed rock material, the Nile brings down with it a supply of organic matter derived from the dead bodies of animals and plants which have lived in or near the river.

Although practically all the land of the Nile valley has been deposited by the river, yet the soil is not entirely uniform in character. As already explained this arises

from the different conditions, as velocity of the current and distance from the river, under which the silt has been deposited. The soils in the northern part of the delta and all other low lying lands in Egypt are liable to become impregnated with common salt—sodium chloride—if not carefully drained so as to keep the salt down to a level where it will be harmless to vegetation. The presence of this salt modifies the character of the soil in which it is found, and is an important consideration for cultivators in northern Egypt. Saltless soil is only got where the land is so high that the salts have been washed away in the drainage water. Irrigation, with drainage, keeps away the salt from the surface soil. Without cultivation and irrigation, the salt rises to the surface by capillarity. Wind blown sand also contributes to giving the soil a variable character.

Compared with soils formed from the rocks on which they lie, alluvial soils are usually very uniform in grain. The river is unable to carry stones and gravel into Egypt and the soil has consequently little or no soil skeleton. The large particles of a soil facilitate cultivation and drainage, and the want of this soil skeleton is severely felt in Egypt. The finer particles, having a larger proportion of surface, are easily weathered to produce plant food, and the spaces between the particles are filled with water, air, or living organisms.

To show the resemblance between the composition of Nile mud and Egyptian soils, the following analyses are given :

Analyses of Nile Mud and Egyptian Soils.

	Suspended Matter in the Nile during Flood Average for (2 years) of August and September Silt.	Good Soil from Tantah (Delta).	Good Soil from Mansourah (Delta).	Good Soil from Etsa (Fayoum).	Good Soil from Matai (Upper Egypt).
Potash	0·53	0·55	0·56	0·63	0·76
Soda	0·57	0·58	0·70	0·72	0·74
Lime	3·07	3·38	3·28	5·53	4·47
Magnesia	2·68	2·88	2·66	2·75	2·89
Oxide of Manganese	0·25	0·22	0·45	0·24	0·26
Oxides of Iron and Alumina.	25·56	23·36	24·90	20·23	24·39
Phosphoric acid (P_2O_5) ...	0·25	0·20	0·23	0·22	0·28
Carbonic acid (CO_2)	0·73	0·67	0·85	3·03	1·10
Chlorine	—	0·09	0·03	0·11	0·10
Organic matter and combined water *	8·82	7·79	7·76	7·38	7·78
Insoluble matter and sand...	57·54	60·28	58·58	59·16	57·23
Containing nitrogen *	0·145	·07	·07	·05	·095

All Egyptian soils do not show such a close resemblance in composition to Nile mud as do the delta samples given above. Some contain more sand and some less; while some, particularly in Upper Egypt, contain more calcium carbonate. (See the analyses of the Fayoum and Matai samples).

In studying the nature of the soil it is convenient to divide it into five parts:—

1. *The mineral part.*—The particles of hard rock material.
2. *The organic part.*—Decomposed animal and vegetable matter.
3. *The organised part.*—Worms, insects, plant-roots, bacteria, and other organisms.

4. *The soil water.*—Infiltration, irrigation, and rain water, with solutions of salts.
5. *The soil air.*

A small part of the mineral matter of the soil is derived from the remains and ashes of animals and plants, but most of it consists of decomposed rock particles of different sizes, shapes, hardness, and composition, depending upon the nature of the rock from which the soil was derived. In sandy soil the particles are comparatively large, while in a clay soil they are mostly very small. This results from sandy soil being largely composed of very hard material (quartz) which is difficult to break up, whereas clay soil is formed from, and in part composed of, soft mineral particles (mica, felspar, etc.) which are easily weathered and broken up into fine material. Pure clay —weathered felspar—and pure sand are equally devoid of plant food. In ordinary soils it is only by the constant weathering of felspar, mica, etc., that a steady supply of available plant food is obtained. Generally, clay soils contain more unweathered felspar, etc., than sandy soils, and hence the former are usually richer in the mineral plant foods. "Loam" is the name given to soils in which the mineral particles are in size, smaller than those in sandy but larger than the fine particles of clay soils. The physical properties of a soil, its drainage, irrigation and cultivation, depend largely on the size of the particles of which it is composed.

The organic matter in the soil is generally known under the name *humus*. The humus consists chiefly of

the dead and weathered bodies of plants, and possesses in itself all the ash elements required to build up new plants. The weathering of humus takes place, in the presence of air and moisture, under the action of bacteria which oxidize it to nitric acid and other bodies available as plant foods. The organic part of the soil contains practically all the nitrogenous plant food of the soil. Besides yielding most important plant foods, a supply of humus in the soil is valuable in that it feeds the organisms in the soil and thereby aids in the weathering of itself and the mineral part of the soil. Its decomposition results in the formation of acids which, dissolved in the water, increase its weathering power. Humus improves the physical properties of the soil by increasing its power of retaining and raising water, by forming a binding material for sandy soils, and loosening and opening up clayey soils.

The organised part of the soil consists of living things, such as plant roots, worms, insects and bacteria. As far as plants are concerned, the bacteria are the most active and most important of the organised matter. They assist or cause most of the weathering processes, and are therefore indispensable in the preparation of food for crops. The plant roots are themselves, to a slight degree, weathering agents, owing to the acid substances they exude and the plants are thus able to assist in the preparation of their own food. Of the insects living in the soil probably more do harm than good.

A supply of air in the soil is necessary to permit of the breathing of the plant roots and of the other living bodies in the organised part of the soil.

The Chemical Properties of the Soil.

The composition of the soil chiefly depends on the minerals of which it is composed and, ultimately, on the rock from which those minerals have been derived. From the rocks of Egypt only a poor, sandy, calcareous soil could be derived, but from the granite and sandstones to the south, the rich Nile mud is obtained. The plants absorb from the soil all matters which exist dissolved in the soil water; some of these substances are plant foods, and others, although entering the plant, are of no use. If dissolved in the soil water, poisons may enter and destroy the plant's life. From the atmosphere the plant absorbs its gaseous foods, oxygen and carbon dioxide; all other food material is taken from the soil. The mineral food for the plant can only be taken up by the plant root when it is dissolved in the soil water. Apart from water, the substances obtained from the soil which are absolutely essential to plant life, are compounds of nitrogen, phosphorus, sulphur, potassium, calcium, magnesium and iron. The plant foods are probably absorbed in the form of nitrates, phosphates, sulphates, etc., and it is convenient to speak of them by those names. Of the total plant food in any soil necessarily only a very small part is soluble and available for the plant. Another part, the surface of the soil particles, is in process of weathering and is slowly but constantly becoming available, while the bulk of the total food, in the inside of the soil particles, is still inert, unweathered and unavailable. All the plant food may at last become available, but at any particular

time only a relatively small quantity of it can be taken by the plant. Thus in a soil containing 0·12% of nitrogen only 1·50% of this total may be available. It is the confusion between total and available plant food which renders the chemical analysis of the soil so very undependable. Thus an analysis may show in the soil a great abundance of phosphoric acid, and nevertheless the soil may be infertile through lack of this plant food in an available form. In short there is practically no reliable method of analysing the soil to ascertain the amount of plant food in the soil which can be taken by a crop. Again, the quantity of available plant food in the soil at one time gives no clue as to the amount which will become available, and which the crop can take, during the period of its growth. Even if the soil could be satisfactorily analysed, and the presence of more than sufficient plant food be detected, yet the soil may be infertile; the soil may be acid, or salt, or the physical properties may be unsuited for plant growth. On the other hand chemical analysis may detect the presence of salts, acids and the absence of any plant food.

A fertile soil must contain the essential plant foods in an available form, and no excess of one or more foods will compensate for the deficiency of any other of the foods. In the words of the Law of Minimum, the fertility of a soil, *i.e.*, the size of the crop it can yield, depends on that plant food which is present in available form in relatively least quantity. Of the various compounds required by the growing plant those of nitrogen, phosphorus and, less often, of potassium are given special importance by their relative scarcity. The other plant foods calcium, magnes-

ium, iron, and sulphur, usually occur in the soil in such comparatively large quantities that they are never specially applied in manuring. The manures generally applied to the soil to increase the crop are the nitrogenous, phosphatic and potassic. The soil may be regarded as a reservoir of plant food which, through the action of the weathering agents, is digested and dissolved to suit the requirements of the plant.

Analysis of a fair soil:—

Nitrogen	0·11 %	= 2.000	kilos. per feddan.
Potash...	0·70 %	= 13.230	" "
Phosphoric acid ...	0·40 %	= 7.560	" "

(Calculated in a layer of soil 30 cm. deep).

This is as much nitrogen as is contained in 73 crops of cotton, and as much phosphoric acid as in 750 crops. It is evident, that even a very poor soil contains far more plant food than is required by an ordinary crop, but it is known by experience that even the best soils give an increased crop when manure (available plant food) is applied to the land. Of course one of the objects of applying manure is to maintain the fertility of the soil. These figures show clearly that the fertility of a soil depends on the amount of food available for the crop and not on the total food as shown by analysis. The nitrogen, in the soil, as nitrates, seldom exceeds 1 kilog. per feddan at any time.

The following table gives the analysis of three soils with their sub-soils, and the crops of cotton produced from each.

ANALYSES OF THREE SOILS AND SUB-SOILS AND THE WEIGHTS OF COTTON PRODUCED FROM EACH.

	No. 1.		No. 2.		No. 3.	
	SOIL	SUB-SOIL	SOIL	SUB-SOIL	SOIL	SUB-SOIL
Organic matter...	5·90	4·70	4·61	4·85	5·92	5·13
Phosphoric acid	0·33	0·20	0·28	0·26	0·40	0·27
Potash	0·64	0·39	0·62	0·51	0·89	0·59
Lime	4·36	3·73	3·84	3·67	5·12	3·79
Magnesia	2·87	2·65	2·52	2·60	2·76	2·87
Iron Oxide and Alumina ...	18·43	16·54	16·19	17·83	17·43	18·90
Insoluble matter	62·94	67·23	68·71	65·57	61·55	63·22
Total Nitrogen...	0·105	0·061	0·075	0·031	0·118	0·105
Nitric Nitrogen	0·0004	0·001	0·0014	0·0002	0·0014	0·0001
Cotton crop	5 kant., 17 okes.		6 kant., 50 okes.		3 kantars.	

Soil No. 2, the poorest soil, produces the largest crop; the soil richest in plant food, No. 3, produces the smallest yield of cotton. If the physical properties of these soils are compared (see physical properties) it will be noticed that soil No. 2 is more permeable and not nearly so tenacious as the other soils. This table is sufficient to show the unreliable nature of chemical analysis as regards the fertility of the soil.

It will be shown later, in dealing with the relation of the plant to the soil, how an excess of any soluble substance in the soil is harmful to the growth of the plant, and this even although the salt be a valuable plant food. Hence either a scarcity or excess of food results in a poor crop.

The soil, however, seldoms suffers from too much plant food; but it is often too salt through the presence of too much sodium chloride, sodium carbonate, calcium chloride, magnesium sulphate, etc. Some salts are more harmful than others, thus sodium carbonate, an alkaline salt, is more hurtful to plant growth than sodium chloride. The reason of this may be due to the neutralising action of an alkaline salt on the plant root juices: the alkaline salt paralyzes the efforts of the plant to prepare its food. Again calcium chloride is a hygroscopic salt and has a tendency to keep the soil in a constantly wet, sticky condition.

Salt soils owe their saltness chiefly to the conditions under which they were formed or exist. Some soils are salt because they were formed at low levels near the sea water; and many are salt because, through infiltration or other cause of high water table, much of what is really drainage water is being raised to the surface by capillarity, evaporated, and the salts left to accumulate in the soil. The very deep lying salt does not usually come to the surface except on low lying lands, but by diffusion, salts can move up in the soil without any upward movement of the body of the water. In Egypt wherever a soil has no drainage salt always appears. Besides the direct effect which the presence of an excess of soluble salts has on the root of the plant and its power of absorption, salts are harmful through retarding organised activity and the preparation of plant food in the soil. Again, the constant soaking of the soil particles in a salt solution, results in the washing out of much of the plant food from the soil when the soil

is undergoing washing and drainage. Hygroscopic and alkaline salts render the physical properties of the soil unfavourable for cultivation and plant growth. When salt soil is watered, the solution of salts is so dilute as to have little effect on the plant, but as the soil dries, this solution becomes more concentrated and more and more hurtful to the plant. Hence, it is evident that salt soils require much water to keep the salts in a harmless state, and to permit of the survival of the crop. Seeds are usually sown on moist or wet soil so that even on salt soil the germination is fairly good, although the seedlings may die later.

The injurious salts found in the soil are principally chlorides and sulphates of soda, and to a less extent, of magnesia. However, when a soil contains soluble sodium salts these react with other soil constituents, and a salt soil will always contain at least certain small quantities of soluble lime salts and other bodies. Soluble carbonates are seldom found in Egyptian soil. Hygroscopic salts (calcium and magnesium chlorides) in small quantities keep the surface of some soils in a wet, sticky state.

It is difficult to say definitely what percentage of salt in the soil affects the growth of the crop. The harmful effect of salts is different with different plants; it depends on the stage of growth of the plant; it depends on the character and distribution of salts in the soil; and it depends on the amount of moisture in the soil. Hence, experiments to ascertain the effect of salts on plant growth, give varying results depending on the special conditions under which they are carried out. From the cultivator's point of view, all salt must be considered un-

desirable. Roughly 0·2% of soluble salt is too much and 1·0% renders the land infertile. With pot experiments 2·0% sodium chloride; 2·0% sodium nitrate; 1·0% calcium chloride; 0·1% mercuric chloride on wheat prevented the production of any grain.

The presence of much acid in the soil is injurious to plant growth. Soil acidity is only found in soils very rich in organic matter, and is due to the decomposition of this organic matter and the formation of complex organic acids. The conditions predisposing to acidity are deficient drainage and aeration, and the absence of anything in the soil capable of neutralising the acids formed. In Egypt, acid soil is practically unknown, as usually the soil is not particularly rich in organic matter and always contains a sufficiency of lime compounds. Good agricultural land should show a neutral or slightly alkaline reaction as these states most encourage the bacterial growth which plays so great a part in the preparation of plant food. Strong alkalinity is as undesirable as acidity.

Of the chemical actions taking place in the soil, the fixation of plant food is one of the most important. When solutions containing compounds of potassium, phosphoric acid, and ammonia, are filtered through a good loam soil it is found that the drainage water contains very little of those bodies in solution. This is partly due to the foods having formed, with certain of the soil constituents, *insoluble* compounds which are unable to drain through the soil. On the other hand, nitrates form no insoluble compounds with any constituent of the soil, and therefore they pass through. Hence, although drainage water contains nitrates

it seldom contains more than a trace of ammonia, potash, or phosphoric acid. Because nitrates are found in relatively large quantities in bare fallow, and because they are not fixed in the soil, the heavy watering of such land results in a loss of valuable plant food. The compounds in the soil causing fixation vary; phosphoric acid is chiefly fixed by forming insoluble phosphates of lime and iron; potash, ammonia and lime are fixed chiefly by interaction with certain chemical compounds called zeolites which are hydrated double silicates of alumina and some other metal. Thus a potassium salt (soluble) with hydrated silicate of soda and alumina (insoluble zeolite) gives a sodium salt (soluble) with hydrated silicate of potash and alumina (insoluble zeolite). When the base of a salt is fixed in a zeolite, the base set free from the zeolite passes into the drainage water combined with the acid of the decomposed salt. It is chiefly because potash is fixed and soda is not that the sea water contains so much more of the latter salt. In the presence of a large amount of salt however, the soda may replace some of the potash in the zeolite, and hence saltness of the soil results in the gradual exhaustion of the fixed plant foods of the soil. Humus in the soil has a certain power of fixing ammonia, lime, etc., probably through the formation of insoluble double humates.

The power possessed by soil to fix plant foods chiefly depends therefore on the presence of zeolites, humus, lime, and iron. In loams and clay soils, these substances occur in much greater quantity than in sandy soil, and accordingly the latter soils are much less active in fixing plant foods.

When soluble manures are added to sandy soils there is little fixation, and the crops respond quickly to the increased supply of available plant food. Again, on sandy soils the drainage water will carry away relatively large quantities of plant food. The power of fixation of any soil is limited, and after a certain quantity of material is fixed the addition of more soluble plant food results in its loss in the drainage water, in its going to the plant in excess, or in its setting up soil saltness. The important results of the fixation of plant food by the soil are: (1) the plant food, as phosphates, potash and ammonia salts, in the soluble manures applied to the soil, and those foods weathered in the soil, are fixed in the soil and so prevented from being lost in the drainage water; (2) the plant obtains a more regular supply of food during the whole period of its growth, and not simply an over abundance when soluble manure is applied.

In connection with this conversion of soluble into insoluble plant food, it might appear as if there were no advantage in applying soluble phosphoric acid and potash to the soil as they are rendered insoluble very soon after being dissolved in the soil water. It must be remembered however, that those bodies are precipitated, or fixed, on the surface of the soil particles, and therefore the insoluble compounds thus produced are widely distributed and finely divided, and are directly exposed to the redissolving action of the soil water and, more especially, to the solvent action of the juices excreted by the plant rootlets. A piece of phosphate of lime lying in the soil, is of much less use to the plant than the same food

dissolved and then reprecipitated on the surface of hundreds of soil particles. There is a great difference in the availability of the potash in a soil particle, and the same potash after it has been weathered and fixed on the surface of many soil particles. When available plant food is spoken of what is meant is: (1) the plant food actually dissolved in the soil water; (2) the fixed plant food slowly soluble in the soil water and in the root juices; (3) the food (manure) which will dissolve on coming into contact with water.

The Physical Properties of the Soil.

If not more important, the physical properties of a soil are at least quite as important as its chemical properties. Many soils well stocked with all the essential plant foods, are far from fertile, simply because their physical properties are unfavourable for plant growth. After glancing at some of the general properties of soils, the soil in its relation to heat, air, and water will be considered. The object of the mechanical analysis of soil, is to separate the mineral particles into classes of various sizes, and thereby to ascertain the "Texture" of the soil. In this separation, the finer particles are obtained by suspension in water and subsequent settling, the remaining coarser particles being passed through special sieves. The mineral particles of all soils vary considerably in size, from the large grains of coarse sand to the finest particles of clay. In every soil, particles of various sizes are found; in sandy soil there is usually a small proportion of the finest clay material, and in most clay soils a

certain amount of fairly large grains are found. The smaller the particles of which a soil is composed, the greater is its power of raising and retaining water. Beyond a certain point, however, so much resistance is offered to the passage of water between the fine particles that the upward or downward movement of water is very slow. The low water capacity of the Facus soil, in the table given below, is due to the extreme fineness of the soil particles. Generally a clay soil can raise water higher than a sandy soil but the water is raised much more slowly. Small particles give tenacity to the soil and render cultivation more difficult. As chemical action only takes place on the surface of the soil particles, fine grained soils present a greater surface to the action of the weathering agents. Further, the smaller particles are usually softer, more easily weathered, and are composed of bodies which are capable of yielding more plant food than the larger particles. However, when a soil consists entirely of very *fine particles it is so tenacious, badly drained, and badly aerated, that the rate of weathering is reduced to a minimum.* Conditions for plant growth are therefore most favourable when a soil consists of a mixture of small and large mineral particles. The large particles, or soil skeleton, open up the soil, increase its porosity, and provide the raw material from which the fine particles are derived. In the following table the material washed off in the analysis is called "clay."

Physical Properties of some Soils.

Sample	Nature	Per cent. composition of mineral particles: Over 0·5 mm.	Under 0·5 mm.	"Clay."	Tenacity: In grams per sq. cm.	Relative.	Specific Gravity	Porosity per cent.	Relative Impermeability	Percent. Water Capacity: by Volume.	by Weight.	Shrinkage per cent.
Facus	Clay	1	43	56	546	84	2·53	52	184	39	30	38
Soil No. 1 ...	Loam... ...	—	61	39	83	13	2·57	47	23	48	39·6	25
Soil No. 2 ...	Sandy-loam.	—	71	29	42	6·5	2·61	49	8	48	37·7	14
Sub soil No. 2.	Clay-loam...	—	56	44	83	13	—	—	44	48	38·5	27
Soil No. 3 ...	Loam... ...	—	61	39	138	21	—	—	50	48	39·2	26
Sub soil No. 3.	Clay	—	49	51	118	18	—	—	25	49·5	39·3	—
Earth nut Soil.	Sandy... ...	5	89	6	6·5	1	2·63	60	1	36	23	0

This table shows the relative properties of different soils examined under similar conditions.

The "Specific Gravity" of the soil is not a point of any great importance. The above figures give the specific gravity of clay soil from 2·53 and sandy soil, 2·63. A cubic metre of dry loose loam soil weighs about 1,300 kilograms, and when wet about 1,700 kilograms.

The "Porosity" of the soil is calculated from the relation of the soil particles to the total volume of soil. Soils which are composed of a mixture of large and small particles have usually the smallest volume of pores. Clay soils have a high "pore-space" but, at the same time, they are

bad conductors of air and water on account of the fineness of the channels between the particles, and hence a "porous" soil may be nearly impervious to water. Again, from the examples in the table given above, it may be noticed that a porous soil has often a small water capacity. The "Tenacity" of a soil is due to the cohesive attraction between the surfaces of the soil particles, and accordingly clay soils, which possess small particles and therefore much internal surface, show great tenacity, whereas coarse sand show very little. The tenacity varies with the amount of water in the soil, and thus wet sand is slightly tenacious, dry sand not at all. Further, the tenacity of a soil is partly due to the presence of colloid or gluey matter. This sticky matter is chiefly found in the finest clay particles, but humus has also a binding effect on mineral particles. In the table given above it will be noticed that to break a column of the Facus soil of 1 sq. cm. section requires a force equal to the weight of 546 grams. Tenacious soils are called "heavy," a term having no relation to their weight but referring to the difficulty experienced in their cultivation. Besides being difficult to cultivate, tenacious soils are poor croppers as the soil is badly drained and badly ventilated, and the growth of the plant roots is thereby restricted. When the soil is just moist, neither wet nor dry, the tenacity is reduced and cultivation is possible. Lime and certain soluble salts coagulate and flocculate the colloid clay, thereby decreasing its tenacity and increasing its permeability.

Relation of the Soil to Heat.

The temperature of the soil has a great influence on the growth of vegetation. The specific heat of the soil is a point of minor importance, for the temperature of the soil under cultivation depends chiefly on the wetness of the land. Up to a certain point, a high temperature, if accompanied by sufficient moisture, is conducive to the rapid growth of the crop and to the activity of the micro-organisms which are preparing plant food. The plant roots are more active, more water is transpired and more food is obtained. Cotton seed sown early is always planted on the warm side of the ridge as the heat ensures rapid and consequently better germination. In different parts of the soil, different temperatures prevail and this tends to maintain a circulation of the soil air. The soil derives its heat chiefly from the sun and, in a less degree, from the hot interior of the earth and the fermentation of the organic matter it contains. Dry rough sandy soil is usually warmer than soils which are capable of retaining more moisture. The coldness of wet soils is due partly to the high specific heat of water, and partly to the loss of heat consequent on the evaporation of water from the surface of the land. On the other hand, sandy soils become coldest at night and the crops growing on such soils are subject to great extremes of heat. The conduction of heat through the soil is most rapid in compact non porous soils. The soil loses its heat by radiation, evaporation of water, and the heating of cold irrigation water. Under the earth's surface there is a belt having a nearly constant temperature,

below this the temperature gradually rises towards the centre of the earth. In Europe, the belt of constant temperature is about 24 metres under the surface; to a depth of from 0·6 to 1·0 metre the temperature of the soil shows daily variations. In the following table the average monthly atmospheric and soil temperatures are given, the latter at depths of thirty, sixty, and one hundred and twenty centimetres.

SOIL TEMPERATURES.

PERIOD	AVERAGE atmospheric temperature.	AVERAGE MONTHLY TEMPERATURES IN DEGREES CENTIGRADE OF SOIL AT:		
		30 cms. depth.	60 cms. depth.	120 cms. depth.
1901				
May	23·0	26·3	25·1	23·2
June	26·7	30·7	29·0	26·1
July	28·0	32·6	30·7	27·8
August	27·8	33·1	31·0	28·8
September	25·1	30·1	28·4	27·7
October	23·3	27·0	26·3	26·3
November...	18·6	21·6	22·7	24·0
December	15·1	17·5	19·2	21·0
1902				
January	13·3	15·1	17·0	18·9
February	16·0	17·0	17·6	18·0
March	17·7	19·8	20·2	19·7
April	20·2	22·5	22·2	20·4

A rise in atmospheric temperature is followed shortly afterwards by an increase in temperature at 30 cms. and still later by an increase at greater depths.

DATE	TEMPERATURE			
	Atmosphere.	Soil at 30 cms.	At 60 cms.	At 120 cms.
13th April, 1902	20·6	22·5	21·8	20
14th ,, ,, ...	24·7	22·5	22·0	20
15th ,, ,, ...	19·0	23·5	22·2	20
16th ,, ,, ...	20·5	23·5	22·5	20
17th ,, ,, ...	22·5	23·5	22·9	20·2

Below 30 cms. there is no hourly change in temperature.

MARCH 3rd 1903 AT:	8 a.m.	10 a.m.	12 noon	2 p.m.	4 p.m.	6 p.m.
Atmospheric temperature	9·2	14·0	17·2	19·0	19·7	17·5
Soil at 30 cms.	16·9	16·9	16·9	17·0	17·05	17·1
" 60	17·1	17·1	17·1	17·1	17·1	17·1
" 120 "	17·8	17·8	17·8	17·8	17·8	17·8

Air in its relation to the Soil.

For animals, a well ventilated room is a necessary condition of health, and similarly for plants, good health can only be maintained in a well ventilated soil. The air in the soil is required for the respiration of the soil organisms and the plant roots. The soil air is naturally richer in carbon dioxide than the atmosphere, and to clear out this gas and maintain a supply of oxygen a constant circulation of the soil air is necessary. The spaces between the soil particles are filled with either water or air and consequently it is the open, well drained soils which are the best aerated. In stiff clay soils, plants probably suffer more from a deficiency of air than from any other cause. In such soils their roots are unhealthy and inactive, and the weathering of plant food is reduced to a minimum. The circulation of the soil air is brought about by the different temperatures of the different parts of the soil, by the differences of temperature of the atmosphere and soil air, by the movements of the soil water and by the diffusion of gases due to the different compositions of the soil air and the atmosphere. Certain crops, like rice, can practically be grown in water as long as this water is kept aerated by

constant movement and renewed; in stagnant water or below the water table no crop roots can live because standing water contains little or no air. In wet soils—soils in which the water table is near the surface—the spaces normally filled with air contain water, and in such soils the plant roots quickly decay. This unhealthy state of the plant root may often be observed in the case of cotton growing on land which is wet at high Nile. The available air in the soil is that which is dissolved in the soil water. For germinating seeds a very free supply of air is necessary, and it is chiefly the lack of air which causes the failure in the growth of seeds which are watered directly after sowing. The nitrogen gas of the soil being dissolved in the soil water enters the roots of the leguminous plants and supplies the nitrogen fixing organisms with matter to elaborate into plant food. Hence the nodules of the leguminous plants are usually best developed in dry sandy soil. Good cultivation and drainage help to insure a good ventilation of the soil.

Water in its relation to the Soil.

A regular supply of water in the soil is absolutely necessary for plant life. This supply must be neither too great nor too little and the water must be constantly moving. Water enters largely into the composition of most crops; it is necessary to dissolve and carry plant foods into the plant root; it tends to maintain an even soil temperature; it softens and makes easier the penetration of roots in the soil; in draining away it removes waste materials and salts; it renders the growth and activity of micro-organisms

possible, and in these, and other ways, it helps in the preparation of plant food. On the other hand, it has certain undesirable functions; in draining it removes plant food from the soil; its evaporation cools the soil; its rising in the soil tends to the deposition of salts in the surface soil; its application washes the smallest particles into and fills up the air spaces thereby increasing the tenacity, and decreasing the ventilation and drainage of the soil.

Soil obtains its water from rain, irrigation or infiltration. Rain water, when its regular supply can be depended on, is the most satisfactory source of soil water. Where rain generally falls in small quantities there is seldom that great dilution of plant food and loss of good material through excess of drainage consequent on the application of a heavy flooding by irrigation. The rain in falling does much good in cleaning the leaves and stems of the plants. In consequence of the supply of water being small the soil particles do not run, and the soil remains loosely packed. Unfortunately rains cannot usually give a regular or convenient supply of water and, of course, the amount of rain falling in Egypt is insufficient for the growth of crops.

By irrigation, a regular supply of water can be fed to the crops, and further, in Egypt, the Nile water is the only source from which fresh soil can be obtained. For improving sandy soil this deposit of mud is very valuable. Well water is naturally devoid of suspended matter and does little to enrich the soil. The great disadvantage of irrigation is the running and packing of the soil particles

and the consequent increased tenacity and impermeability of the soil.

In digging a well it is observed that the soil gets moister and moister until eventually a point is reached at which the spaces between the soil particles are entirely filled with water. Here the soil is said to be saturated with water and the level of this saturated soil is called the "water table." The level of the water table is constantly shifting; it rises when irrigation is applied, when the Nile is high and when neighbouring lands are flooded; it falls as the land dries, as the Nile falls and as the outlet of its water is lowered. The water below the water table is always moving onwards and downwards until it discharges itself into a drain or sea. As water and air cannot occupy the interspaces of the soil at the same time it follows that below the water table there is not much air and plant roots cannot thrive. Hence in low-lying lands the depth for plant roots is restricted by the proximity of the water table to the surface level. A wet soil is not necessarily quite saturated with water, and, in fact, in dry countries a retentive soil is to be preferred to a dry one. Again a soil too dry for berseem may be a good soil for barley, a soil too dry for rice a good soil for maize. On the other hand a saturated soil —except the saturation is with moving water—is bad for all crops and no plant root can be healthy if it dips too far below the water table. To allow a full root development, the water table at high Nile should not rise nearer to the surface than about 1¼ metre. Land near high canals is often kept constantly wet, and the plant food solution constantly dilute, but the water table is not neces-

sarily high. Further, infiltration, like subsoil water, is deficient in gases dissolved in it. The effects of too high a water table are: (1) The plant roots are unhealthy and food is slowly prepared on account of the lack of oxygen in the soil. (2) The solution of plant food in the soil is rendered very dilute and the plants, more especially if young, will be unable to absorb a sufficient volume from which to extract the required amount of food. (3) Salts and acids (waste products) will accumulate in the soil. (4) The amount of water evaporated and the high specific heat of water, renders the soil cold and thereby retards plant growth. Wet soils can only be improved by lowering the water table by drainage and, if the water is from infiltration, by lowering the source from which the subsoil is being supplied with water. Heavy waterings are occasionally advisable to destroy obnoxious insects, but otherwise frequent and light waterings give the best results; heavy waterings at long intervals cause an unequal growth of the crop.

The great advantage of irrigation is that the water supply can be regulated. The quantity of water required by a crop varies with the particular conditions of the cultivation. Thus level land requires less water than uneven soil; salt soil must be kept pretty moist in order to keep the salt solution dilute and harmless; sandy soil requires more water than heavy soils; crops in small beds require less water; green fodder crops require a moister soil than the cereals. In summer, except at high Nile, more water is required than in winter. In order to avoid the washing away of plant food, bare land is only watered under

exceptionable circumstances. The aim in watering should be to apply as light irrigation as possible. Crops generally, and cotton in particular, that have been water-starved must not be watered too heavily when nearing ripeness. Too heavy watering, at a late period of the plant growth, delays ripening and causes the production of new shoots to the detriment of the resulting crop. Of the many points of importance in the relation of water to the soil the following require to be carefully considered:—the water capacity, the shrinkage on drying, the permeability and the movements of the water in the soil.

The "Water Capacity" of the soil:—the capacity of the soil to absorb water when placed in contact with it, and the capacity to retain water after saturation, as after irrigation, are properties of the greatest importance. On the former property depends the power of the soil to draw water from below, and on the latter the power of the soil to retain water against the action of gravity. Both these properties depend chiefly on the texture of the soil. Fine grained soils can absorb and retain most water. When the land is newly flooded the power of retaining water is the more important. When the soil is drying the power of the soil to draw water from below, is of greater importance. This last is more or less a measure of the capillary power of the soil and it is measured, comparatively, by standing the ends of tubes of soil in a basin of water and finding the amount of water absorbed in relation to the weight or volume of soil. The presence of humus and colloid bodies in the soil increases its water capacity. In the same way, as will be pointed out under

capillarity, rolling the soil increases its water capacity. Plants absorb their water from a certain volume of soil and hence the water capacity of soils is better expressed relative to the volume of soil.

"Shrinkage" is the name given to the diminution in volume consequent on the loss of water from the soil. From the table* it will be observed that the finer the soil particles the greater is the shrinkage; whereas in sandy soils the volume scarcely changes when the soil is dry. In clay soils it is the decrease in volume of the colloid bodies on drying which is the chief reason of the great shrinkage of these soils. Naturally, on watering, such soils expand, but, for some time at least, the watering will not bring the soil back to its original volume; as a certain amount of permanent contraction will take place owing to the closer packing of the soil particles. It is this firm packing which gives the soil its power to support the heaviest buildings. The shrinkage takes place both vertically and horizontally. When the surface is rapidly dried, it shrinks and the lower soil layers being still in a state of expansion, the outer layers crack. This cracking causes great damage by breaking the plant roots and by restricting their growth to the lump of soil on which they are growing. Further, the surface of the fissures present a large area from which the soil water is quickly evaporated. On the other hand the cracks are more or less indispensable for the ventilation of the soil which, when the soil is firmly crusted, would be reduced to a minimum. To prevent the rapid drying

* Page 39.

of the upper layers of the soil, and the subsequent cracking, heavy soils require to be continually fassed. The more heavily a soil is watered the greater is its temporary increase in volume, and, on drying, the larger and deeper are the cracks.

A soil is said to be pervious or "permeable" when it allows water to drain easily through. Soils through which water cannot pass are impervious or impermeable. It must be noticed that a "porous" soil is not necessarily a pervious one, for the pores, although abundant, may be too small to allow of the passage of water. This may be seen in the case of the Facus soil (see p. 39) the porosity of which in the loose state amounts to 52 %, and yet it is the most impervious soil. Soils with few, large pores—sandy soils—are much more permeable and more easily drained than clay soils. The impermeability of the fine clay soils is due partly to the small size of the interspaces and partly to the colloid bodies which swell and close these spaces. Clay soils are made more porous by the addition of humus, of sand, and of lime, etc., which flocculate the finest clay material. A soil with particles of about an equal size is more porous than a mixed soil where the small particles fill up the larger interspaces and the soil is more closely packed. By loosening the packing, cultivation increases the permeability of the soil. The firmly packed subsoil is usually less porous than the soil unless, of course, the subsoil is of a more sandy nature. The Facus soil which is permeable in laboratory experiments is probably quite impervious in its naturally compressed state. Generally the permeability and tenacity vary inversely. Most salts increase

the permeability of the soil by flocculating the fine clay particles, but alkaline salts like sodium carbonate increase the tenacity and impermeability. Too porous sandy soils can scarcely be kept sufficiently moist for the growth of most crops, and excessive watering of such soils is apt to cause a great loss of plant food through drainage. In impervious soils, the circulation of water is bad and the ventilation is insufficient, and generally plants grow very badly. Thus the Facus soil is quite incapable of producing a crop. With such a soil draining can have little effect and the only method of satisfactorily improving the physical properties would be by mixing with it a large volume of sand, an expensive, but fairly permanent improvement. The greater part of the irrigated alluvial soil of Egypt suffers from excessive tenacity, shrinkage and impermeability, and poor crops are due far more to those defects than to any deficiency of plant food.

The movements of water in the soil are dependent on the general soil properties which have already been considered. The plant roots in the soil are constantly absorbing water from the soil in their immediate surroundings, and this part of the soil is drawing on the water further from the plant. Hence, practically at all times, there is a slow but constant movement of the soil water towards the plant root. This will be more clearly shown a little later. In the soil there are other and greater movements of water, movements which are active equally in cultivated and uncultivated soil. For convenience, these may be classed as upward, downward and horizontal and are referred to under the terms capillarity, drainage and infiltration

respectively. The term percolation may include all those movements.

"Drainage," or the downward motion of water, is due to the action of gravity and therefore acts in a direction towards the centre of the earth. It is only natural that water should tend to fall, but this falling will only take place or continue when there are no other forces equal to or greater than gravity preventing the downward motion of the water. In clay soils the downward motion is difficult or impossible on account of the great resistance caused by the friction of the water passing down between the very fine particles of soil. Again, the surface attraction of the soil particles has power to overcome the force of gravity. This attraction however is of importance only when there is no excess of water and hence in ordinary loam and sandy soils after each irrigation there is a certain amount of drainage. The greater the head of water over the surface of the soil the greater is the pressure acting downwards and the greater is the amount of water lost by drainage. It follows that stiff clay soils should receive heavy waterings to overcome the resistance of the particles to the passage of water. When there is no drainage, the waste products of plant life in the soil, and salts, collect and tend to render the land infertile. Hence, although by drainage soils lose a certain amount of plant food, this loss is far more than compensated for by the good effect produced by the washing away of undesirable bodies. The water table in the soil is raised by drainage water and is lowered by increased evaporation and by the water finding a lower

outlet. Drainage from the river, canals and higher lands —infiltration—is a great source of subsoil water. In Egypt infiltration often raises the water table to very near the soil surface, and evaporation without drainage causes saltness of the soil. In low-lying lands the only possible way of lowering the water table and preventing saltness is by drainage, either by draining the soil or tapping the

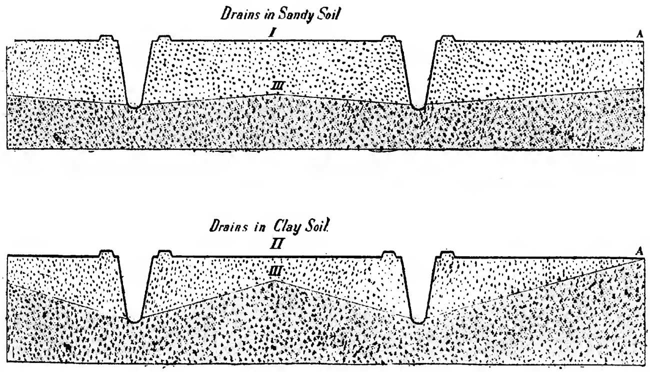

FIG. 1.—LOWERING OF THE WATER TABLE BY DRAINS.

infiltration water from the higher neighbouring lands by means of an infiltration drain. The degree to which the water table is lowered by a drain depends chiefly on the permeability of the soil. Close to the drain the water table will be lowered to nearly the level of the water in the drain; further away the water table will be higher owing to the resistance offered by the soil to the horizontal motion of the water. Half-way between the drains the water table will be nearest to the surface.

In sandy soils which offer little resistance to the passage of water, drainage may be very easily and successfully accomplished, whereas in clay, which offers considerable resistance, the water table midway between the drains may be too high unless the drains are sufficiently near to each other. In Egypt the object of drainage is more to keep the soil from saltness than to lower the water table to the level best suited for plant growth. To obtain the same reduction of water table, deep drains may be made at a greater distance apart than shallow ones.

The horizontal motion of water in the soil takes place under the action of gravity and external pressure. This motion is closely allied to drainage as the weight of the water is the moving factor. Infiltration may be regarded as a special case of drainage in soils, where the sinking water is unable to find a downward discharge and therefore takes a more or less horizontal direction and filters into the neighbouring soils. Infiltration includes upward motion when this is caused by pressure of water from behind, and it includes motions which are partly vertical up or down and partly horizontal. Infiltration is usually caused by water from some high level canal penetrating the surrounding soil. At first, the water draining from the canal drains downwards, but this gradually raises the water table, and with the head of water behind, the water is forced along in a horizontal direction. Naturally the result of infiltration is worst when the water table in the soil is already high, but even where the water table is low, the decreasing permeability of the soil as greater depths are reached offers even more resistance to the drainage of

water, and the water which is forced from the canal spreads in a horizontal direction. Hence when land suffers from infiltration water there is always wet soil, but not necessarily a high water-table. The damage resulting from infiltration is that caused by the saturation of the soil with stagnant airless water and the salting of the soil consequent on the evaporation of that water.

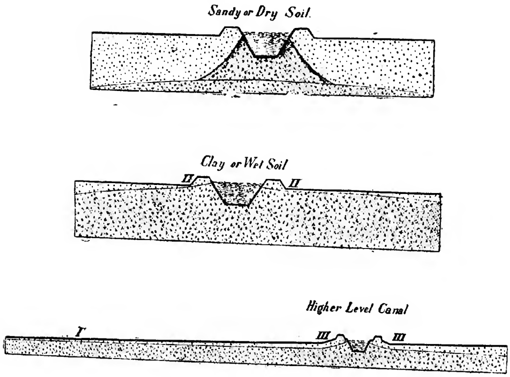

FIG. 2.—INFILTRATION OF WATER FROM CANALS.

We know that the soil above the water table contains moisture and it is important to know in what way that water is raised there and how it is held.

The explanation lies in the property possessed by water in common with all liquids of exhibiting the phenomenon of surface tension.

We may study this property as follows :—

(1) If we dip a small particle into water and withdraw it we find it covered with a thin film of water which

persists there. Why does not all the water fall off? The reason is that there are forces acting in the surface of the film which balance the weight of the water.

(2) If we touch the above particle with a second, we find the film spreads over the two continuously.

(3) If the two particles are unequal in size the water stands more deeply on the small one.

Now applying this knowledge to the case of soils we see that it is by the surfaces of the particles that a soil may hold water.

Now the area of the surface of the particles will be greater in a fine soil, and we expect too the depth of the film to be greater, and so a fine soil ought to hold more moisture than a coarse one. This we know to be the case in practice. A clay soil holds more water than a gravel.

The creeping or spreading of the water film from one particle to another takes place in all directions until a condition of equilibrium is reached. Now if the thickness of a film is interfered with at any place there is at once a flow of liquid to restore the balance. Thus if we remove a little water from one particle the others next it at once share some of theirs with it.

This affords an explanation of the rise of water in the soil. The particles above touch the film below and the water in it is shared with them, so the film spreads upwards and draws continuously on lower supplies.

The question arises—Why then does not the water rise quite to the surface in all cases? This is met by the fact that the resultant of the forces in the surface of the film is finite and so can only support a given weight. It has

to support the weight of the water raised, and so when this reaches the full value of the force, equilibrium is attained.

This upward movement of water in the soil is generally described as due to "capillarity" and in this sense the word is used when discussing soil physics. When the water can rise from the water table to the surface, and we get evaporation there, we shall have a constant stream of water through the soil from below. In general the smaller the particles of soil the higher can the water rise by capillarity but the more slowly. The particles being small the interstices are small and more resistance is offered to the flow of the water.

The power of the soil to retain water, its water capacity, is the result of surface tension. Capillarity, raising water from a high water table or from infiltration water, is a common cause of soil wetness and saltness. In a loose friable soil, where the soil particles are widely separated, capillarity has only a very limited action whereas in firmly compressed soils the soil pores are fine, the particles are close together and water can be raised to a considerable height. Hence, soil is rolled to increase its water capacity and capillarity ; it is "fassed" to hinder the action of capillarity and prevent water being raised quite to the surface.

The rate of evaporation from the surface of the soil depends on the dryness of the air, the amount of water in the soil, and the rate at which capillarity can replace, from below, the water removed from the surface. Evaporation dries and cools the soil and the extraction of water causes the soil to shrink. Evaporation causes the salts in the soil water to collect on the surface of the soil and

it causes a constant circulation of the soil water by disturbing the equilibrium between surface tension and gravity. In soils having growing crops, this stream of water is more towards the plant roots than towards the surface, as the aerial part of the plant prevents evaporation from the soil surface. A land stocked with plants loses much water by the transpiration of plants, but evaporation from the surface of the soil is less than on bare land.

The following table shows the relative powers of capillarity of the soils which have already been considered.

RELATIVE CAPILLARITY OF CERTAIN SOILS, DETERMINED BY THE RISE OF WATER IN TUBES AFTER STANDING FOR SOME TIME.

SAMPLE	After 24 h.	After 48 h.	After 72 h.	After 96 h.	After 120 h.	After 144 h.	After 168 h.
	rise cms.	rise cms.	rise cms.	rise cms.	rise cms.	rise cms.	rise cms.
Faeus...	3·0	5·5	6·8	8·0	8·9	9·7	10·7
Soil No. 1...	42	56	65	72	77	80	84
„ „ 2...	44	58	66	73	77	80	—
„ „ 3...	36	47	54	60	65	68	73
Subsoil No. 3	36	48	58	62	67	71	77
Earthnut Soil	46	48	50	51	51	51	—

THE BIOLOGICAL PROPERTIES OF THE SOIL.

The biological properties of the soil are those characters which it possesses in virtue of the various forms of animal and plant life found in the soil. Without the presence of living bodies, the soil is practically an inert mass unsuited for the cultivation of crops. In fact, the weathering of the soil particles for the preparation of available plant

food is brought about largely by the direct or indirect action of the soil organisms—the animals living in the soil and chiefly insects and worms. These, boring through the soil, open it up to the action of weathering agents and facilitate the passage of the plant roots. Many of these animals derive their food from the organic part of the soil to obtain which they eat the soil, and passing it through their body, give excrements richer in available plant food than the original soil. Further, the physical properties are also improved, as the soil leaves the worms or insects in a finely pulverised state. Of course, many of the insects usually found in a soil are enemies of the crop, and the good they do to the soil is far more than counterbalanced by the harm done to the crops. It is worthy of note that whereas the plants prepare food for animals, the animals by giving manure assist in the preparation of plant food.

Of the plant life in the soil, the micro-organisms or bacteria and the crop roots are of greatest importance. Every living root, while it is taking in food, is also active in giving out waste products of the plant cells or excrements. The acids excreted by the root attack the insoluble soil particles and dissolve matter from them. Different plants excrete juices of different dissolving power and therefore some plants can do much more than others in the preparation of their own food. It is partly on this account that no two crops can be grown on the same soil with equal success; while lupins can derive sufficient mineral food from a very poor sandy soil, many other plants would be quite unable to prepare their food from the scanty material at their disposal.

The organic matter in the soil, consisting of the dead bodies of animals and plants, contains all the elements required to build up new plants. Hence, the humus is a most valuable, in fact indispensable, part of the soil. As humus, it cannot be taken by plants and hence the preparation of available plant food from it is one of the most necessary and important processes taking place in the soil. The importance of humus is evident when it is remembered that it is the only part of the soil which can yield the very valuable food material, Nitrogen. Neither chemical nor physical agents have under ordinary circumstances much effect on organic matter. For example, a piece of wood kept in air or pure water remains unchanged whereas when it is buried in the moist soil it quickly decays. In dry desert soil, which contains no micro-organisms, the wood remains unchanged. Even the juices excreted by the plant roots have an inappreciable effect on organic matter. In short, the micro-organisms alone may be regarded as the preparers of useful material from the soil humus, and a soil without micro-organisms is not fertile, however much humus it may contain. These small organisms are to the plant what the digestive juices are to the animal; both prepare food, one for absorption by the root hair into the plant, the other for the passage of the food from the outside into the animal system.

Different soils have naturally different numbers of bacteria living in them. In any soil the number of bacteria is greatest a short distance under the surface, where they find the most favourable conditions for life. Here they find a good supply of organic matter to serve as food,

a fairly even temperature, a supply of air and water and no sunlight. Below the water table few bacteria can exist on account of the insufficiency of air. In a soil there has been found :—

	micro-organisms.
In 1 gram of soil at 20 cms. below the surface	650,000
,, ,, 100 ,, ,, ,,	36,000
,, ,, 140 ,, ,, ,,	700

and going deeper still micro-organisms cease to exist. It can easily be understood that, in spite of their minuteness, bacteria, occurring in such large numbers, must have a great effect on the character of the soil. While some bacteria are indispensable to soil fertility others are distinctly hurtful. Some bring about processes of oxidation others reduction: the former can only live in the presence of oxygen and the latter are often of a harmful nature. A few of the most important processes controlled by micro-organisms will be shortly reviewed, attention being directed to the result rather than to the special action of the micro-organisms.

The "Putrefaction" of organic matter is brought about through the deoxidising, or reducing, action of certain bacteria. These bacteria obtain their oxygen from the combined oxygen in the compounds they attack. It is this class of bacteria which flourishes in the interior of manure heaps and in masses of organic matter, until the breaking up of the mass admits oxygen and allows of the action of other organisms. The products of putrefaction are usually complicated bodies giving off a strong disagreeable odour. The "decay"-causing bacteria are the most active in disintegrating organic matter and producing

simple bodies which are nearly ready to feed the plants. The decay bacteria cause processes of oxidation and are therefore only active when air has free access to the fermenting mass. By these bacteria, the products of the life of the putrefactive germs and raw organic matter are converted into simple odourless bodies. Generally, when organic matter is undergoing fermentation the putrefying and decay bacteria are both active, the former in the inside of the mass and the latter on the surface where there is a plentiful supply of air. The fermentation of "Cellulose," the woody part of organic matter, is brought about by a great variety of micro-organisms. The black colour of soil and decomposed organic manure is largely due to the black carbon derived from the dehydration of cellulose. In the presence of air, cellulose is completely oxidised to carbon dioxide and water. When this oxidation of cellulose is going on rapidly, as in a rich manure heap, there is always a very considerable rise in temperature. Through the action of the putrefying, decay, and cellulose bacteria organic matter is at last completely reduced to such simple bodies as water, carbon dioxide, ammonia, and carbonates, sulphates and phosphates of the mineral bases contained in it. The chief nitrogenous compounds in urine are changed to ammonia compounds through the action of certain micro-organisms. This change may take place quickly and the ammonia produced gives a strong ammoniacal odour to stables and manure heaps. The decay, and other bacteria, prepare the ash constituents of organic matter for plant feeding, but the nitrogenous bodies are not available for the plant until they have undergone a further fer-

mentation. This next step, the oxidation of ammonia to nitric acid, is brought about by the "Nitrifying" bacteria. These organisms require for their growth a suitable temperature, moisture, darkness and a good supply of air. The nitrification of ammonia takes place in two stages. The first stage, the oxidation to nitrous acid, is brought about by the "Nitrous" bacteria; the oxidation of the nitrous to nitric acid is the work of the "Nitric" bacteria. To prevent the accumulation of too much acid, where fermentation is taking place, the soil must provide a sufficiency of lime to neutralise the acid as it is produced. The changes taking place in organic matter in its preparation for plant feeding may be thus represented:—

ORGANIC MATTER

HUMUS

Amido-bodies.	Carbon dioxide.	Water.	Mineral matters, e.g. phosphates, sulphates, etc., of potassium, calcium, etc.
Ammonia.			
Nitrous Acid.			
Nitric Acid. (appearing as nitrates e.g., calcium nitrates).			

It is evident that farmyard manure, and organic matter generally, is only valuable as plant food provided it comes under the action of the bacteria just considered. Besides producing nitrogenous and other plant food from organic matter, these bacteria are indirectly of the greatest help in rendering the mineral part of the soil of use to the crop. The acids produced during their activity, and in

particular carbonic acid, give the soil water a very much increased power of dissolving mineral matter.

The bacteria found in the soil are not all working for the benefit of the crop. The "Denitrifying" bacteria reduce nitric acid and set free nitrogen gas, and in this way cause a loss of valuable material. Fortunately, the bad micro-organisms are only active in soils which are in a poor physical state. They thrive best in badly aerated, ill-drained soils and, unless under exceptional circumstances, they probably do very little harm.

In nature, a comparatively small proportion of the total nitrogen is found in a combined state and, as plants generally cannot use nitrogen gas as a food, it follows that the fixation of this gas to form compounds is essential for the cultivation of crops. The combined nitrogen found in coal, in tafla, and in soil, has almost entirely been fixed through the action of life. Certain lowly organised plants, and one of the bacteria in particular, have the power to take nitrogen gas from the atmosphere and unite it with other bodies in the form of organic matter. Hence, this micro-organism which can take nitrogen gas and change it into compounds available for feeding the higher plants is of the greatest importance in agriculture. These nitrogen-fixing bacteria live either in the soil or inside the roots of certain of the higher plants. When living in the soil, the activity of these bacteria is evidently much less than when they are living in the tissues of the plant root. Whether they exist in the root however or in the soil, they are always collecting and enriching the soil with a most valuable plant food. The only plants which have

roots suited for the entrance and activity of those bacteria are apparently the leguminous plants,—like the bean, berseem, lupin, lentil, earthnut and fenugreek. After entering the root of a suitable plant the bacteria increase

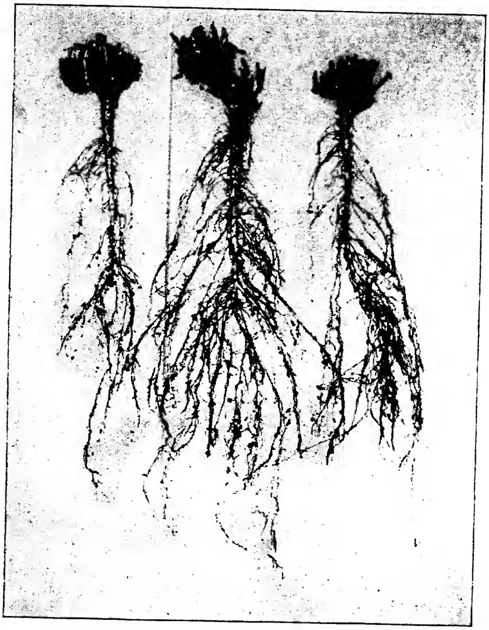

FIG. 3.—BERSEEM ROOTS (AFTER FIFTH CUTTING) SHOWING "NODULES."

in number and the tissue in which they reside swells forming little nodules.

The accompanying illustration shows the little nodules on the roots of berseem after the fifth cutting of the crop.

Living in the tissue of the plant, the micro-organism takes the nitrogen gas which has entered the plant root and unites it with other bodies to form compounds which are taken by the leguminous plant to build up its body. On the other hand the bacteria derive their mineral and other food from the sap of the plant with which they are living. On account of the manufacturing power of their lodgers, the bacteria, the leguminous plants are independent of the soil for a supply of nitrates. Such crops can therefore be grown on sandy soil devoid of organic matter where barley or any other crop would fail through lack of nitrogenous food. The farmer does not think of the help he is obtaining from these little bacteria, but he knows the enriching effect of growing berseem, beans, lentils and earthnuts, and in every rotation the nitrogen-collecting crops find a prominent place.

The following determinations of nitric nitrogen will show how, in bare land, available nitrogen is ever being made, but that if the land is flooded this food may be washed away.

AVAILABLE NITROGEN	Nov. 27th	Dec. 28th	Feb. 19th	March 30th	May 4th
	%	%	%	%	%
Land ploughed, left fallow and not watered	·000098	·000362	·000393	·000490	·000551
Land ploughed, left fallow but watered	·000098	·000329	·000328	·000393	·000390

The bacteria in the soil may be divided into three classes; those which have no effect on soil fertility, those which have a good effect and those which have a bad effect.

The first class includes very many bacteria which are the micro-organisms of diseases. Parasitic, putrefying, and denitrifying organisms do more or less harm in the soil. The good bacteria, those of decay and nitrification, and the fixers of free nitrogen are those which must be favoured in soil cultivation. The good bacteria are helped by having the soil in a good state of cultivation, by having the soil well ventilated and well drained, and by supplying organic manures. Wet land, or soil containing salt, is unsuited to the requirements of the good micro-organisms. The activity of bacteria is greatest when the medium in which they are found has a temperature of about 38° C. and generally decreases with a higher or lower temperature.

The good bacteria act directly or indirectly in preparing plant food. The decay, nitrifying, and symbiotic (nitrogen fixing) bacteria act directly on the raw materials and prepare them for use by the plant. A soil containing much humus but none of the above micro-organisms is absolutely infertile. Thus salt, wet, or sour soil, may be rich in raw plant food, but if it does not contain the good bacteria, it is incapable of producing a crop. Applying sulphate of ammonia to the soil is only of use when the soil contains nitrifying bacteria to change it into available plant food. Without the nitrogen-fixing bacteria the supply of nitrogenous food would become less and less and the fertility of the soil would gradually be exhausted. The bacteria preparing plant food are ever active, and hence on bare land there is an accumulation of soluble plant food which may be washed away if the land is heavily flooded.

Indirectly, the bacteria assist the growth of crops by

producing heat and acids. The acids resulting from the decomposition of organic matter are dissolved in the soil water and give it the power to attack and weather the mineral foods for the plants. In fact, unless slightly acid, the soil water is of little use as a weathering agent and plants would obtain but little food. Without the activity of these organisms, humus and organic manures would be of no value, and the mineral particles of the soil would form practically an inert mass changing too slowly to admit of the growth of anything but the most meagre crop.

Before closing this short consideration of the soil, it is necessary to glance at the position of the plant in the soil. The relation existing between the plant and soil can be best explained diagrammatically. The following diagram is a supposed section through the plant root and soil.

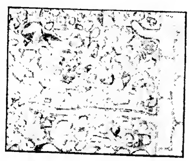

FIG. 1.—ROOT HAIR IN THE SOIL.

The soil particles are sketched and shaded; the soil water is represented by shading; the air by unshaded spaces. A root hair, much magnified, leaving the root extends through the section. For the sake of simplicity and clearness certain unimportant factors will be overlooked.

In a well drained soil the water is present in the pores of the porous particles, in the smaller interspaces and as

a coating on every particle, but the larger interspaces of the soil are filled with air. When these also contain water the soil is said to be saturated or "wet."

The thicker roots of the plant fix it securely in the soil but play practically no part in the absorption of the food. This is done by the root-hairs on the rootlets which branch out from the larger roots in all directions in search of food. The root-hairs, found only on the newer portions of the rootlets, are very minute tube-like growths from the surface cells and into them the protoplasmic layer and cell-sap of these cells extend. They have a mucilaginous coating in which many soil particles are imbedded, and thus they are brought intimately into contact with the water of these particles, and through them with that of all the other soil particles in their immediate neighbourhood. At the root-hair there are therefore two watery solutions, the cell-sap and the soil water separated from one another by a membrane consisting of the cell wall and the protoplasmic layer. This membrane is very tender and is easily permeable to water and to certain dissolved substances.

All the water and mineral matters of plants enter by the root-hairs, and to explain the passage of these from the soil into the plant some reference must here be made to the two processes of Diffusion and Osmosis.

When a soluble substance is placed in water it dissolves and in time will distribute itself uniformly through the water. This it does by diffusion or the gradual wandering away of its molecules in among the molecules of the water. Osmosis cannot be so simply defined but it may be regarded as a case of diffusion complicated by the presence

of a more or less permeable membrane. In explanation of this consider the case of a strong solution of a substance separated from a weaker solution or from water by a membrane permeable to water and to the substance. In time the two solutions will come to the same strength, partly by water moving from the weak solution to the strong one, partly by the dissolved substance moving from the strong solution to the weak one. As the former movement is much the greater of the two the strong solution gains in volume at the expense of the weak one; in other words there is a flow of liquid from the latter to the former. Were the membrane to be impermeable to the dissolved substance then, with a solution on one side and pure water on the other, uniformity of composition could never be attained, but water would continue to pass into the solution in an endeavour to make the two solutions equal. If the result of this accumulation of liquid on the one side of the membrane is to set up an increased pressure there, a time will at last come when this pressure will balance the inward flow of water and no more water will enter, or more correctly, what enters will exactly balance what passes out. As a matter of fact probably no membrane is completely impermeable to dissolved substances, but some allow certain substances to pass through them only very slowly. Such is the character of the protoplasmic layer in the root-hair. Easily permeable to water and to many of the salts dissolved in soil water, it is almost impermeable to many of the substances found dissolved in the cell-sap. Osmosis, the name given to such phenomena as have just been described, has therefore to do with

the passage of the molecules of liquids and dissolved solids through membranes, and before any such movement can go on it is necessary that the two liquids or solutions concerned be able to mix with one another, and that the membrane be permeable to at least one of the liquids. And now to apply this to the case of the root-hair in the soil.

Under normal conditions the cell-sap is a stronger solution than the soil water, and so more water enters the cell than leaves it; that is, there is an inward flow. As the substances dissolved in the soil water are on the whole readily diffusible, these pass in with the water and so the plant obtains the mineral matters necessary for its growth. The water and dissolved matters so absorbed are passed up through the plant to the actively growing points, and what water is not built up into the body of the plant finally leaves it as transpiration water. As the plant is steadily losing water in this way, and the substances dissolved in the cell-sap do not readily diffuse out into the soil, it follows that the cell-sap will continue to be a stronger solution than the soil water and the inward flow of water will be maintained.

Many of the soluble salts passing into the plant are there changed into other forms which do not readily diffuse out again, and so the original substances continue to enter. Should, however, a substance be taken up and remain unchanged, then after a time its accumulation in the cell-sap would result in the setting up of an outward diffusion which would eventually balance the inward one.

Although, as already stated, the dissolved matters of

the sap do not readily pass out through the protoplasmic layer, a certain amount of outward diffusion goes on. Among the substances thus passed out one of the principal is carbonic acid which aids considerably in the solution of the soil particles.

In the case of salt soils, the soil water is a fairly strong solution, and the inward flow is much reduced. As the land dries, the solution in the soil becomes stronger and stronger, and an outward flow may at length be set up. This is fatal to the life of the plant, and hence the importance of plenty of irrigation water in the cultivation of salt lands.

The water taken in by the plant is drawn not only from the particles in the immediate neighbourhood of the root but also from comparatively distant particles. In explanation of this consider the case of a group of particles touching one another. If this group receive water, this water will distribute itself throughout the pores and over the surfaces of the particles in such a way as to be in equilibrium. This it does under the influence of what is known as surface tension, a property of liquids which cannot be fully entered into here but upon which the behaviour of the surface of a liquid depends. If water be drawn from any particle of the group, this equilibrium is disturbed and there is a flow of water from all the other particles towards the said particle. In this way a root-hair, when it draws water from a particle imbedded in its mucilaginous layer, starts a current of water towards itself from every particle in its neighbourhood, since every particle of soil may be regarded as in communication with

every other particle through the medium of the water-envelopes. This flow of water from particle to particle explains how a plant may be able to supply itself with water from a comparatively dry soil, and how it may be nourished by particles with which its roots never come in contact, by the gradual solution of these particles in the soil water.

When a soil is very wet the water is easily drawn from its particles, but as it dries it becomes more and more difficult, as a thin layer of water is more firmly retained on a particle than a thick one. A plant can take a very large proportion of the water from soil but cannot completely dry it. A time at last comes when the osmotic movement into the cell cannot overcome the attraction, between water and particle.

In a fertile soil there must always be air spaces from which the soil water may constantly dissolve and carry a supply of air to the plant. In a rice field, constantly irrigated, there may be no air spaces, but their loss is compensated for by the air which is always present dissolved in running water.

The micro-organisms in the soil live in the soil water and in the wet organic matter, and doubtless they are able to move about in the larger spaces between the soil particles.

When the farmer buys a soil he obtains a certain capital of raw plant food, a physical apparatus more or less suited for the growth of crops, and certain micro-organisms to carry on the preparation of plant food. Further, he stipulates for a water supply, and an annual deposit of

mud—on basin land—to make up for the soil which has been exhausted in growing the crops on his land. This deposit is a necessary condition of continued fertility. In Europe, instead of a yearly deposit, the farmer buys in his land stones and rocks from which the weathering agents provide him with a new supply of mineral particles.

CHAPTER III.

CULTIVATION.

In the last chapter the soil was considered from the point of view of its relation to the life of the plant; here it will be treated of in its relation to cultivation and the production of crops. To begin with, it is necessary to distinguish between the part of the soil which is ploughed or otherwise tilled and the part lying below, beyond the reach of ordinary tillage operations. The upper part which is ploughed is called the "soil" and the part below, the "subsoil." The surface of the subsoil on which the sole of the plough runs when tilling the soil is usually much compressed and is called the "plough-pad." The depth of the soil is between 16 and 20 cms., varying with the depth of tillage; the subsoil is usually much deeper than is required for plant growth. In Egypt the soil and subsoil are very similar in character, nevertheless there must be some difference, otherwise the continual cultivation of the surface has no effect. The mineral particles of which the soil and subsoil are composed are seldom of exactly the same character. Thus the soils and subsoils of samples 2 and 3, of the last chapter (p. 38) show marked differences. Even when the mineral particles are exactly the same, the soil is richer in available plant food than the subsoil for the following reasons:—

1. The soil has not been so long deposited, it has not borne so many crops and is therefore in a less exhausted condition than the subsoil.

2. The soil contains more plant food for it receives a little from the rain, it gets fresh virgin soil from the irrigation water, the manure is applied to it, and the dead leaves, stems, and most of the roots of plants are left on or in it.

3. The plant food in the soil is more available for the plant because near the surface the weathering agents are more active.

4. The nitrogen collecting bacteria of the nodules on the leguminous plants are chiefly confined to the soil, and the rich residue of those crops enrich the soil with nitrogenous plant food.

5. The soil contains more air and is more penetrable and therefore in it the plant roots are larger and healthier.

Since the subsoil is not tilled, it is more closely packed and harder than the soil and although it might contain as much total plant food yet it would, under ordinary circumstances, always contain less available food for plants on account of the slower rate at which weathering takes place in it. The best subsoil is a lightish loam: a sandy subsoil is deficient in water and a clay subsoil is too wet and tenacious for the healthy growth of plant roots.

The nature of a soil is an important factor both in regard to the growth of crops and the cultivation of the soil. In Egypt the soils are sandy or loamy or clayey. The loam has the most general distribution, the clay occurs in small patches, and the sandy soils are principally found skirting the edges of the deserts. The mineral characters of the soil and subsoil show great variations even within limited

areas. The following adjoining soils and subsoils (see page 38) show this:—

Soil.....	No. 1	contains	39 %	"clay" and is a	Loam soil.
"	" 2	"	29 %	" "	Sandy-loam soil.
"	" 3	"	39 %	" "	Loam soil.
Subsoil	" 2	"	44 %	" "	Clayey-loam soil.
"	" 3	"	51 %	" "	Clay soil.

Sandy soils pass gradually into loam, and loam into clay, and between these three great classes of soil there are, loamy-sand or heavy sand, sandy-loam or light loam, clayey-loam or heavy loam, and loamy-clay or light clay.

Sandy soils usually consist of hard unweathered particles, and contain little plant food, either mineral or nitrogenous.

They are very permeable, have a small water capacity, and hence require much or rather frequent irrigation. Heavy waterings drain rapidly through sandy soils. Containing little water, sandy soils are subject to rapid changes of temperature and are the warmest soils and therefore produce early ripening crops. Owing to the absence of "clay" sandy soils are very easily tilled. Manures act rapidly in them but have little lasting effect. Organic, insoluble manures are best suited to sandy soil as they supply the soil with humus, help to pack it more closely, increase its power of holding water, and are less liable to be carried away in the drainage water. Farmyard manure, sewage, abattoir, bone and green manures are best; soluble manures like coufri, tafla, nitrate of soda, and superphosphate, must be carefully applied in small, frequently repeated doses. The crops and fruits grown on sandy soil give smallish yields, but on account of the dryness

and warmth of the land the crops are healthy and ripen early. On the sandiest soils, the crops which give the best return and at the same time improve the soil, are the nitrogen-collecting leguminous crops, earthnuts, lupins, lucerne, and berseem. Well manured vegetables do exceedingly well on sandy soil. Henna, barley and sesame are grown on sandy soils. Millet requires a less moist soil and therefore does better than maize on dry sandy soils.

The properties of clay soils are in direct contrast to those of sandy soils. Strong clays are usually the worst soils from the farmer's point of view. They are exceedingly difficult to cultivate and only give poor results. Milder clays are not so objectionable. Clay soils have a very high water capacity, are impervious and consequently are often wet. They require little water, yet the floodings may be heavy as there is little fear of excessive drainage. They have a high but slow capillary power, and on drying they shrink and crack to the detriment of the growing crops. They are cold soils and are very badly ventilated. Clay soils are difficult to cultivate and even after the most exhaustive tillage seldom give a fine tilth. To minimise cracking much fassing is required, and unless the soil is worked when only slightly moist, it is apt to puddle into hard lumps. By mixing clay soil with sand a loam soil with suitable physical properties may be obtained. Clay soils usually contain much mineral plant food but, on account of their power of fixation of plant food, and their lack of air, they are often deficient in available food, and the action of manures is very slow. Farmyard manure is suitable for clay soil as it helps to lessen its tenacity. All

soluble, quick-acting manures may be applied to heavy soils without fear of loss. The wetness, coldness, and lack of air of clay soils make them unhealthy and late in cropping. Such soils are highly unsuitable for fruit and vegetable culture. On clay soils poor in nitrogen, lupins, lucerne, berseem, helba or fenugreek, guilban or vetchling, and beans may be grown as there is little outlay with those crops and they open up and enrich the soil. Wheat, cotton, maize and sugar cane can be successfully grown on the better clay soils. The Facus soil of last chapter was characterised by its cultivator as being incapable of producing a crop (p. 39).

The great bulk of Egyptian soils may be classed as heavy or light loams. The sandy-loams are easily cultivated, the clayey-loams are usually richer and more suited to cotton cultivation. The properties of loam soil approach those of clay on the one side and sand on the other. For nearly all crops a loam soil is physically the best; chemically it may be deficient in plant food, or it may be salt or wet. A loam soil, however, has a greater chance of being rich in available plant food than either clay or sandy soil, as its good physical condition is favourable to the growth of nitrogen-collecting bacteria, to the accumulation of dead vegetable matter (as more plants grow on it) and to the weathering of the materials in the soil. All crops will grow well on loam with the single exception of earthnuts which requires a very free soil. Clay soils are called "heavy" because they are "stiff" to work; "cold" or "wet" because they are badly drained and often wet; "inactive" because they respond slowly

to the application of manures; "black" because they contain little of the light coloured sand. Sandy and sandy-loam soils are "light," "warm," "dry," "active" and "red." Salt loam and sandy soils may be sweetened by washing; or, in the case of sand, better by warping; stiff clay must be otherwise treated.

The fertility, or size of the crops obtained from a soil, depends on the composition of the soil, the power possessed by the soil to fix plant foods, the absence of an excess of acids and salts, on the texture, water capacity, capillary power, permeability, tenacity, and on the presence of good, and absence of bad, micro-organisms in the soil. Hence it is impossible to definitely say that loam is invariably better than sand or clay soils. In wet climates heavy clays are most objectionable as their wetness prevents their tillage; in dry countries except where there is a plentiful supply of water sandy soil is of least value for cropping. In cropping it is usual to plant lupins on the poorest soil, barley on poor soil, and wheat on the strongest clay; but this is a purely financial arrangement, the best crop of lupins, barley, and wheat, being obtained from the rich loam soils.

The cultivation of the soil is undertaken to ensure the production of larger crops by increasing the amount of available plant food, and by improving the physical properties so that the plant will be better able to get and absorb this food. The more food a plant obtains from the soil, the greater is the amount of atmospheric food (carbon dioxide) it can take up for the use and profit of the farmer. Cultivation in its wider sense includes all

processes by which the soil is disturbed or moved or by which the character of the soil is changed. The term "Tillage" includes all operations by which the soil is disturbed or moved. Amelioration includes those processes by which the character is changed by adding or taking something from the soil. Cultivation in the crop will be fully considered under each special crop so that it is unnecessary to enter into any detailed consideration of the subject in this chapter.

The processes of amelioration deserving special note are Drainage, Washing, Warping and Manuring. Drainage is the means employed to carry away excess of soil water, that is to lower the water table in the soil. Washing (in conjunction with drainage) dissolves and carries away from the soil injurious salts and soluble plant food material. In place of washing, the surface incrustation of salt is sometimes, on a small scale, removed from the land by the kassabieh. Warping consists in running Nile flood water on to land and allowing it to stand until the mud is deposited, when the clear water is run off and the land is again covered with muddy flood water. This can only be carried out where there is an abundant supply of flood water. Warping frees the soil from salts and is an excellent method of improving the quality of sandy soil by the deposit of the rich Nile mud.

Manures are bodies which contain, relatively to soil, a high amount of plant food in a more or less easily available condition. They are applied to the soil with the object of increasing the amount of food *available* for the crop. In manuring, that quantity and variety of manure should

be applied which will return the largest nett profit and not necessarily the largest crop. There is no satisfactory method of testing the soil in its relation to the production of the best yield except by applying to the crop itself. In other words the condition of the soil for plant growth can only be ascertained experimentally. Manures are fully dealt with in a later chapter but considering the importance of the question the following few notes may not be out of place. The soil of Egypt is usually deficient in nitrogen and phosphoric acid, and very occasionally in potash, hence those are the substances which require to be applied to the soil in manures. Those plant foods occur in manures either in an easily soluble, slightly soluble or insoluble state. The plant food in an easily soluble state is most valuable since it is most quickly absorbed by the crop. Insoluble plant food in manure is of much less value, because manures containing only such plant food but poorly fulfil the object of manuring which is the supplying of available plant food to the crop. Easily soluble plant food is contained in nitrate of soda, sulphate of ammonia, tafla, sebach coufri, superphosphate, dissolved bones, kainit and sulphate of potash. Slightly soluble plant food or partly soluble and partly insoluble is contained in farm-yard manure, and sewage. The plant focd in bones and natural mineral phosphate is insoluble.

Crops which have a long period of growth—cotton, sugar cane and certain vegetables, as Jerusalem artichoke, globe artichoke, asparagus, etc., should be manured with manures which contain the plant food in all the three stages of solubility or at least in the first two. Crops which receive very much water and crops on sandy soil should

not be manured with too soluble plant food. Soluble manures must be applied to crops with a short period of growth or to crops which receive very little water. Crops should generally be manured when they are growing, but in the following cases the manure may be applied before sowing. (1) When insoluble manures or only very slightly soluble manures are applied, (2) when the manure is very bulky as farmyard manure, (3) when the crop will receive only very little water, e.g. wheat. The manures must be applied to growing crops when the plants are free from dew, and lumpy rich manures must be powdered before application. Manures are mixed to obtain (1) a cheap general manure, (2) a manure containing particular plant foods (3) a manure containing the plant foods of different degrees of solubility. After mixing the manures they should be applied immediately to the soil, otherwise the constituents of the mixed manure may react on one another. Thus when nitrate of soda is left mixed with superphosphate there may be a loss of nitrogen. When sulphate of ammonia is mixed with slag there may be a loss of ammonia. When superphosphate is mixed for some time with slag there is a loss of solubility. And generally when artificial manures are left mixed they form hard lumps. Theoretically, the crops which require manure are (1) those which produce valuable out-turns, (2) those which take much plant food and have a long period of growth, like cotton and sugar-cane, (3) those which take little or much plant food but remain on the land only a short time, like maize, sesame, and most vegetables, (4) those which have a weakly developed root system, like flax. In every rotation a part

at least of one of the winter, and one of the summer crops should be manured. This is usually accomplished by manuring part of the cotton and maize crops.

Manures are applied to the land in three ways, (1) Broadcast before or after sowing (2) in the furrows before or after sowing, (3) at the foot of each plant after or just before thinning. The accompanying illustration shows the various methods of distributing manure on ridges after sowing the crop. On ridge I the manure is applied to the side of the ridge below each plant; in II the ma-

FIG. 5.—METHODS OF APPLYING MANURE TO COTTON.

nure is distributed along the bottom of the drill; on ridge IV the manure has been sown broadcast after thinning, and is bad as the manure is applied so high that it touches the stem of the plant, which will suffer when the moisture on the plant dissolves the strong chemical substances of the manure. It is also bad because part of the manure lies higher than the level of watering and can therefore be of no use to the plant.

The diagram (Fig. 6) is intended to show the subsequent movements of the manure when dissolved in the soil water. On the first ridge, where the manure has been applied below

each plant, the manure is dissolved by the irrigation water and passes downwards and inwards, since the centre of the ridge is unwatered. Hence none of the manure will pass to the next ridge. When the water has passed down a certain distance it will be recalled owing to the surface soil becoming dry when its water is evaporated. The water with the manure dissolved in it will slowly be drawn upwards directly in the path of the plant root. In passing up and down, the manure-laden water keeps in contact with the plant roots. When the soil is quite dry, the only manure which will appear at the surface will be a slight deposit between the original position of the manure and the top of the ridge. The manure deposited between the plant and the crest of the ridge will be of no further use to the crop, as water will never be applied high enough to redissolve and carry it to the plant roots. The quantity of manure rendered inactive in this way is exceedingly small. If, however, the manure were applied along the drill, there would be a deposit of inactive manure along the whole crest of the ridge instead of only a little between the plant and the crest. Some of the manure applied to the bottom of the drill would pass over into the plantless side of the neighbouring ridge, and there would be a greater loss by drainage on sandy soil.

On the centre ridge no manure has been applied : on the outer, the manure has been broadcasted. The manure up to the level of watering on both sides of the ridge is dissolved, passing downwards and inwards with the irrigation water. Part of the food solution will come into contact with the roots of the plants, but much of it between the

plants will not be within reach of the plant roots. When the surface dries, the food-laden water passes up again and is partly absorbed by the plant; but most of the manure rises to the surface, where it is deposited after the evaporation of the water. The very darkly shaded crest of the ridge shows where this manure will ultimately be deposited and rendered inactive. A careful study of those diagrams

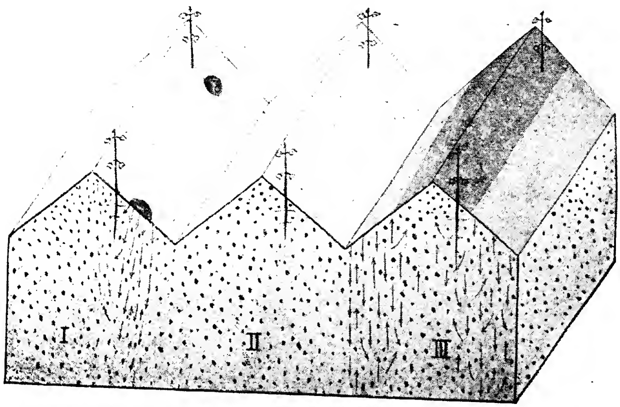

FIG. 6.—DIAGRAM ILLUSTRATING MOVEMENT OF MANURE WHEN DISSOLVED BY IRRIGATION WATER.

should show the most economical method of applying manure. Rich manure should be sown on the plant side of the ridge between the plant and the bottom of the drill ("techbeech"), it must not be put in contact with the stem of the plant.

Passing on to tillage operations it will be better to first consider the general object and effect of working the soil. The ultimate object aimed at is an increase in crop and a

financial profit. The better the tillage the larger is the crop obtained and hence the greater is the amount of plant food which the crop has been able to take. This increased vigour of the plant is the result of the effect of tillage on the chemical, physical and biological properties of the soil. The tillage is only satisfactory when the soil is in a loose, friable condition; that is, when the tilth is fine. The soil tends to form itself into a solid mass which gradually becomes more tightly packed, and offers ever more resistance to the spread of the plant roots and the entrance and action of the weathering agents. Irrigation, by carrying down the finer soil particles and packing them into the air spaces, decreases the porosity and permeability of the soil while increasing its tenacity. Naturally, fine clay soils pack most closely and therefore require most cultivation.

The physical effect of tillage is that the soil is thrown open and left loose, allowing a free passage into it of water and air. The soil is pulverised, large pieces are broken up, and a greater surface is presented to the action of the weathering agents. The finely pulverised soil forms a better medium for germinating seeds, as the seed and soil come into closer contact and better germination is got. Further, in fine tilth, the young seedlings, being covered with a loose and equal layer of soil, are better able to develop their roots, and to send their stems into the atmosphere. The loose soil offers less resistance to the spread of plant roots and as the quantity of water and air is regulated, the plant root becomes larger and healthier. It can readily be understood that plants with large roots draw their nourishment from a greater volume

of soil than plants with small roots, and are consequently able to obtain more food and give larger crops. The accompanying illustration is of two wheat plants of the same age; the larger having been grown on soil which had been better cultivated. The plant from the poorly

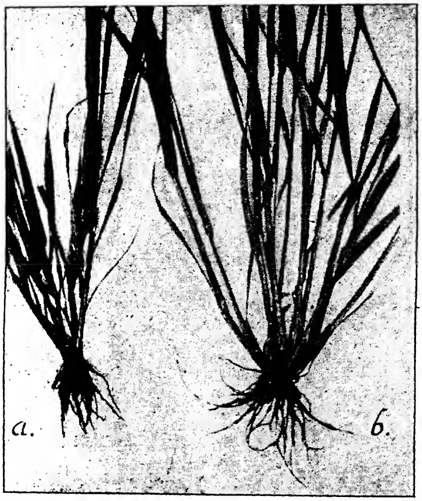

FIG. 7.—ROOTS OF TWO WHEAT PLANTS OF THE SAME AGE, SHOWING GREATER DEVELOPMENT (IN b) BY BETTER CULTIVATION.

cultivated soil has smaller, less spreading roots and has fewer smaller stems.

The biological effects of tillage are that bacteria, other organisms, and the plant roots are healthier and more active, and in consequence more of the plant food in the soil is dissolved for the feeding of the crop. The

increased activity results in quicker oxidation, and the production of more heat and acids which later help in weathering the mineral part of the soil. The organisms in the roots of the leguminous plants are better developed; they obtain more nitrogen gas and are able to fix more of this substance to the clear profit of the farmer.

The chemical effects of tillage are chiefly the result of the greater activity on the part of the living bodies in the soil. The total result of good tillage is an increase in the root system of the crop, the absorption of more food from the atmosphere, the fixation of more nitrogen to enrich the land and the farmer, and the quicker decomposition of the bodies in the soil.

The fineness of tilth obtained from expending a certain amount of labour varies with the character of the soil. The production of a good tilth in clay soils is always difficult but it is made easier when the soil is manured with bulky organic manures, when it is mixed with sand, and when large quantities of lime are applied. Salt, nitrate of soda, and sulphates generally, assist in destroying the puddling tendency of clay soils when they are dissolved in the soil water. Carbonate of soda in any considerable quantity in the soil renders it more sticky and difficult to pulverise. The ideal tilth is obtained when the soil clods are broken up so that each particle is separated from its neighbour, and the particles are well mixed in relation to their former positions. A long exposure of the open soil to the atmosphere—barefallowing—results in a better tilth, as the natural elements have longer time to act and consequently leave a greater impression. The gradual drying

of the open soil, and its heating and cooling, cause the soil clods to crumble away, more especially when the air is very moist and the soil has been cultivated when in a proper state. A long exposure to the atmosphere has the further advantage of checking the growth or killing off injurious insects and fungi. In reviewing the various tillage operations, it is rather difficult to settle the real function of, for example, the native plough: its action is something between that of a plough and a cultivator. Similarly the zahaffa combines some of the functions of the harrow and the roller. The tillage operations which it is proposed to consider are ploughing, subsoiling, ridging, cultivating, zahaffing, levelling, fassing, and weeding.

It is most convenient to define ploughing as the operation of turning over the soil. The turning over is often far from being complete, but at any rate ploughing turns over more soil than any other tillage operation. The objects of ploughing are: firstly, to change the position of the soil so that the next crop may have a layer of fresh soil to feed on, and so that the rich surface layer may be turned down to the plant roots, and the exhausted lower part of the soil may be brought to the surface to recover under the action of another set of weathering agents. Secondly, to mix the soil so that the plants will obtain a regular supply of food in every direction in which their roots may travel. Thirdly, to loosen and free the soil, to destroy its packing and make it friable. Lastly, to kill the weeds which are ever ready to rob the plant of food and space. Land should be ploughed when it is neither too wet nor too dry, in fact it is best ploughed when it offers least resistance to the

plough. When heavy land is ploughed a little too wet, it puddles, and the particles become closer packed than they were and on drying it forms hard bricks which defy all ordinary efforts to produce a fine tilth. Land which has thus been puddled retains the bad effect for several crops. The weeds turned up when ploughing soils in a damp condition suffer little hurt, in fact by cutting them in a wet condition their number may be increased rather than diminished. Too dry soil is turned up in large clods which demand a great amount of labour to reduce to a fine tilth. Roughly, a soil is ready to plough when the surface has a dry appearance and is beset with fine cracks and when the plough keeps fairly clean, turning over a ridge which can be reduced to powder by light pressure. In ploughing up berseem, the land should turn over in an unbroken ridge the surface of which is finely cracked and not glossy and sticky.

Ploughing fallow	with	18 %	moisture	gave	a friable tilth.
,, ,,	,,	22 %	,,	,,	cloddy ,,
,, up berseem	,,	18 %	,,	,,	fairly friable tilth.
,, ,,	,,	24 %	,,	,,	cloddy tilth.

The tillage of the soil causes a great loss of moisture, so that with excessive cultivation the soil may be so desiccated that all organised activity may be stopped and the preparation of plant food brought to a standstill, and although a fine tilth may be got, yet the full benefit of the action of the weathering agents in the open soil will be lost. Hence too much ploughing may really do more harm than good, and to prevent this while obtaining a fine tilth

the use of heavy rollers, cultivators, and harrows is a great help. The native plough is not so apt to out-dry the land, but even with it, after four or five ploughings the soil is usually in a more or less inert state. When the land is ploughed in a good condition, three ploughings are ample, if the land is ploughed too wet or dry it cannot be pulverised with twice this amount of labour. A well cultivated fallow should feel equally yielding under foot, not alternately hard and soft, and it should be free from weeds. The land is most easily cultivated after cleaning crops, that is to say crops which have been fassed or otherwise cultivated. Tillage is most difficult after winter cereals. Land which is being prepared for sowing seed in moist soil must be cultivated as quickly as possible to minimise the loss of moisture which is required for the germination of the crop. If land has been ploughed in a too damp condition, it should not be pressed by the zahaffa or other implement; but pulverisation is helped if such soils are harrowed directly after ploughing. It is better to plough wettish land with the native implement, as it is lighter and is less apt to puddle the soil than European ploughs. After the soil has dried, a heavy roller will produce the finest tilth. To expose the largest surface of upturned soil to the atmosphere, the depth should be to the breadth as 1 is to 1·4: when the depth is fifteen centimetres the breadth will be twenty one. However in order to be able to go deep and still have a moderate draught, it is often necessary to have the breadth a little more than the depth. In cross ploughing, a broader and deeper furrow may be taken without the

plough draught being beyond the power of a pair of oxen. The native plough under ordinary circumstances runs about sixteen centimetres deep, and the balance plough twenty; both are run deeper, two to four centimetres, when cross ploughing.

When the land is ploughed to a greater depth than twenty centimetres, the operation is called "subsoiling." Subsoiling is carried out by a special plough, by a European followed by a native plough, or by steam tackle. Subsoiling may entail the mixing of soil and subsoil, or it may be carried out by simply stirring the subsoil without bringing it to the surface. Subsoiling permits of and encourages the production of a more extensive root system, it regulates the porosity and permeability of the soil to an increased depth, it ensures a more extensive preparation of plant food by the weathering agents, it roots out deep seated weeds, and consequently in nearly every case gives an increased crop. This increased yield is most pronounced in the case of deep-rooted plants and least with cereals grown directly after the subsoiling. Before undertaking extensive subsoil operations in which it is intended to mix the soil and subsoil, it is necessary to first try the effect of this tillage over a small area because sometimes when the subsoil is of an undesirable nature, it is best to keep it as far out of sight as possible. It would be a great mistake to mix a heavy loam with a clay subsoil; on the other hand the mixing of a clay with a sandy subsoil or vice versa would have a good and lasting effect. Simply stirring a bad subsoil would always give favourable results. Mixing soil with raw poor subsoil, and burying the good soil in a

region of slower weathering, is not always successful in increasing the yield of the first crop grown under the new conditions. Hence the full benefit of subsoiling may not be felt until one or two crops have been taken. The effect of subsoiling should last for a good long time, and except on the best subsoils, and where manure is liberally applied, little advantage is to be gained by constant subsoiling. Mixing the soil and subsoil must always be cautiously undertaken, and at all times when the subsoil is disturbed, the full benefit of the tillage will only be got when the land is heavily manured with farm yard manure containing much organic matter. A convenient method of supplying organic matter to a subsoiled land is to grow a crop of berseem and plough the whole into the furrow.

The next tillage operation to be considered is ridging which is carried out by means of the plough or the fass. In the case of raising ridges for dividing the land into beds the battana is of great use on lightish soil. The crops which are grown on ridges could be sown on the flat, but the ridges have the following advantages:—(1) The soil is drier, and the loose top of the ridge ensures aeration of the soil and prevents general cracking. (2) The ridges are warmer than the level, at least on one side. (3) The seed and seedlings can be protected by planting them on the sheltered sunny side in winter, and on the cool side in summer. (4) The crop is more easily watered. (5) The crop can be conveniently cleaned. Lastly the ridge is composed of open soil which is favourable to the formation of tubers and well budded canes. The dryness and warmth of the sunny side of the ridge is of the greatest advantage

in assisting the germination of cotton seed while, for the after treatment of the cotton, the ridges make the crop easier to lightly water and the bottom of the stems are protected against repeated wettings.

In January, nine days after watering, the north side of a ridge contained 24·3 % of water, and the south side only 22·6 %. The following table will sufficiently show the difference in temperature of different sides of ridges. The side temperatures were taken at four centimetres under the surface the others at a depth of ten centimetres. It will be noticed that the south side is always about four degrees centigrade warmer than the north, and that the west is slightly warmer than the east side.

SOIL TEMPERATURES.

TIME	AVERAGE TEMPERATURE OF THE AIR	TEMPERATURE OF THE RIDGE			
		North side.	South side.	Centre.	Furrow.
Jan. 13th 4 p.m. ...	13°·0 Cent.	14°·5	20°·0	—	14°·0
" 14th 8 a.m. ...	12°·0 "	8°·1	12°·2	—	10°·6
" " 4 p.m. ...		14°·0	17°·8	13°·3	—
		East side.	West side.	Centre.	
Jan. 15th 8 a.m. ...	11°·0 Cent.	11°·1	11°·1	11°·7	—
" " 4 p.m. ...		14°·4	15°·6	—	—
" 16th 8 a.m. ...	13°·5 "	8°·3	10°·6	11°·7	—
" 17th 8 a.m. ...	14°·3 "	10°·0	11°·1	12°·8	—
" " 4 p.m. ...		15°·0	18°·3	14°·4	—

Sowing on the crest of the ridges is scarcely suited to Egyptian conditions, as on the top of the ridge there is no shelter, and in deep fassing the plant roots would be damaged. The height of the ridge will depend on the breadth and on the nature of the soil. On poor soil the ridges are made closer together, as the plants on such soil are small and require a smaller growing area.

Crops which are sown on the flat are ridged off into beds. The smaller the beds, the greater is the amount of land lost in the ridges, but the easier it is to water the crop. The beds are made small when water is scarce, when the land is sandy or not level, and when the crop is one of tall growth. When the crop is laid out in small beds, it can be much more easily and more lightly watered, and frequent light waterings are always better than a heavy flooding.

"Cultivators" are implements for stirring the soil. After the soil has been turned by the plough, in many cases cultivation is as good as further ploughing. It costs much less, but with one pair of oxen it is impossible to cultivate as deep as the plough can go. On the other hand, steam cultivation can go much deeper than the ordinary plough. Cultivators are better for opening up the soil than the plough which turns it over, for in ploughing there is always a certain amount of compression. The cultivator can only be used after the land has been ploughed and broken up so as to permit of the easy passage of this otherwise heavy implement. In this country the "Grubber," on account of its strength, its simplicity and the ease of regulating its depth, does very good work and saves

much time in preparing the land for cotton. The objects of cultivating are (*a*) to pulverise and open up the soil, (*b*) to mix the soil (*c*) to pull up weeds (*d*) to cover seeds. In destroying weeds, the cultivator does better work than the plough, as the latter is apt to cut and spread weeds while the former pulls them to the surface to dry and die. Cultivators are useful in covering seeds, more especially if the land is to be watered directly after sowing, when the seeds require to be covered with a finer layer of soil than it is usually possible to obtain with the plough. European harrows perform the function of very light cultivators and have the advantage of covering more land per day.

Zahaffing is a tillage operation which is characteristically Egyptian. It combines rolling and harrowing without being exactly similar to either operation. As a cultivator or harrow the zahaffa is used to cover seeds, and as a roller it compresses the seed bed. It is also used as a pure roller to break down clods. Cultivating has already been considered, so it is only necessary to consider zahaffing as far as its action results in compressing or rolling the soil. As a roller or compressor, the zahaffa compresses the soil, smoothes and levels the surface, kneads down clods, and disintegrates the roots of weeds from the loose tilled soil. After sowing seed, the zahaffa is used to compress the soil for two distinct reasons. (1) The compression packs the soil against and around the seed, and the seed comes into closer contact with the soil particles and with their coating of water. In this way the germination of the seed is surer than if the seed lay in loose soil from which it would scarcely be able to draw enough water for germination. (2) The compres-

sion packs the soil, decreasing the large air spaces and increasing the number of fine capillary tubes. Hence, by reason of its increased power of capillarity the soil is enabled to draw more water from the subsoil. This ensures a moister seed-bed from which the seeds will be able to extract water for germination. It naturally follows that wet soil should be lightly zahaffed or not at all, whilst dry soil should be heavily rolled if the seeds are to germinate without irrigation. Land which is ploughed wet must not be zahaffed until it dries, and then the zahaffa is rather light to make much impression.

Levelling is an operation of the greatest importance. On uneven land more water is required, and the crop cannot be equally watered, and consequently a poor unequal crop is produced.

Fassing or hoeing is the most characteristic and most necessary tillage operation in Egypt. The outlay in fassing the cotton and maize nearly equals the expense of all the other tillage operations of the crop. The objects of fassing are: (1) to destroy weeds, (2) to cultivate the surface of soil, (3) to mix the surface soil, (4) to incorporate manures with the soil, and (5) to form a layer of loose soil on the surface which prevents extensive cracking, and thereby conserves the soil moisture. Fassing is undertaken in the growing crop whether this is growing on ridges or on the flat. In Europe the same work would be done by the horse hoe or in the garden by the hand hoe. In summer, fassing entails much very hard work unless it is carried out at the proper time. The land must not be so wet that the soil sticks to the fass nor so dry that large hard

lumps are fassed up. If land is taken when just moist and slightly crusted, the work is easier and more satisfactorily accomplished. Fass work is so important that it is necessary to closely review the objects of fassing.

It has been stated that fassing is necessary to destroy weeds, and the importance of weeding will be considered below. When fassed, the surface of the soil is always cultivated, and the soil is brought more fully under the influence of the atmospheric weathering agents. However the fassed surface is soon desiccated and rendered devoid of micro-organism activity, and consequently it is doubtful if the cultivated upper surface contains any more food than the lower undisturbed layers of soil. Fassing is but seldom undertaken with a view to mixing the soil, as this can be more cheaply done by other means. In fassing crops on ridges, land is brought to the plant root from the neighbouring ridge; this is a useful but not necessary function of fassing. After applying manure to growing crops, it is necessary to cover the manure with a thin layer of soil, to prevent its being carried away by the irrigation water. The crop is not fassed *after* manuring but rather the manure is applied *before* an ordinary fassing. In other words, there is no special fassing given entirely for the sake of covering the manure.

Crops are not usually fassed with the object of destroying weeds, for there are often no weeds when fassing is undertaken; they are not fassed to cultivate the surface nor to mix the soil, nor are they specially fassed to incorporate manure with the soil. Hence it follows that they are fassed with a view to the attainment of the fifth object, namely the

formation of a layer of loose soil on the surface to prevent extensive cracking. This is the important point to be considered in fassing; the other effects, although beneficial, can only be regarded as incidental. It is now necessary to see the effect of covering the land with a loose layer of soil. As soon as the crop completely shades the soil, fassing is stopped. In fact, covering the land with a loose layer of soil—fassing—has about the same effect as shading it with plants. The shade or loose layer of soil, prevents the rapid outdrying of the upper layers of the soil, and consequently prevents the rapid formation of a hard crust and large cracks. It is necessary to clearly recognise that the chief object of fassing is to cover the land with a loose layer of soil which prevents the rapid out-drying of the upper layers, and that consequently the hardening and cracking of the soil is diminished. Preventing the out drying of the soil results in a saving of soil water, but *per se* this is of little importance except on unirrigated land. Experiments at Ghizeh have shown that during summer, land which is fassed retains four weeks after watering as much moisture as unfassed land two weeks after watering, and that three weeks after watering, the soil which has been fassed contains about two and a half per cent more water than the unfassed soil. A light fassing is more satisfactory for this purpose than a deeper one, as the fassed soil whilst preserving the moisture in the lower layers is itself dried out. Indirectly, the result of light fassing is of the greatest importance, because it permits of less irrigation and the soil does not require to be so deluged with water as to make the solution of plant food in the soil too dilute.

A strong solution of plant food in the soil is a necessary condition for the growth of young plants which are only able to absorb a comparatively small quantity of water. In this small quantity of water they must find much food, which cannot be the case if they get too much irrigation water. To save the crops from being irrigated, the land is fassed equally whether there is little or much irrigation water available, whether the soil is wet or dry. Low-lying, wettish land really requires more fassing than dryer soil, not to save water, but to render further irrigation unnecessary. Fassing prevents loss of water, hardening and shrinking of the soil in the following way: when the surface of the soil is exposed to the hot dry air water is rapidly evaporated from its surface. As the surface layer dries it draws on the water below which rises up by capillarity. Hence a constant stream of water is moving up the soil to be evaporated and lost. By fassing, the capillarity is stopped and therefore the loss of water. The loose layer of soil on the surface is separated from the undisturbed soil by large air spaces across which water cannot pass by capillarity. This loose layer is soon desiccated, but it protects the lower undisturbed surface from the drying effect of the hot air. In the same way, the surface evaporation is reduced when the soil is shaded by plants or when covered with a layer of tibn or other loose material. When the surface water is saved by fassing, the soil does not become so hard, it contracts less and there are fewer or smaller cracks. Plants cause a great loss of deep soil water which is evaporated from the leaves, but this and fassing causes the soil to shrink more gradually and more

vertically. The soil becomes more compressed instead of forming a hard crust as when only the surface is rapidly dried. The reduction of surface evaporation prevents the too rapid rising of water and plant food in the soil, and the consequent deposition of plant food on the surface of the soil. Fassing prevents excessive hardening of the soil crust, and the deep cracking which proceeds when land is allowed to dry without protection. When irrigation water is applied to land it washes the finer soil particles into and blocks up the air spaces. The soil on drying becomes very firmly packed and forms a hard crust which is about as porous as a brick. Slowly dried soil sinks when contracting, rapidly dried land contracts horizontally. At first, the cracks are about four centimetres deep and do little damage. With further drying, the cracks get deeper and cause the rupture of many of the plant roots. They limit the spreading of the roots of the plant to a very small volume of soil and in this way are of the greatest possible hindrance to the growth of the young plants. The deepest cracks, as in the basin lands, do great damage to the oldest and deepest rooted plants. The primary reasons for fassing may be stated as being: (1) to avoid the necessity of frequent irrigation, and consequent dilution of the plant food, (2) to keep the surface open so that air may easily enter, (3) to prevent the soil from deep cracking, whereby plant roots may be killed or plants may be isolated on clods of soil.

Whilst emphasising the essential results of fassing, of course due weight must be given to the incidental advantages already mentioned. Land which has been heavily

watered tends to crack most and deepest, and therefore requires the most careful fassing. The cracks in the soil open deeper and deeper, ever doing more damage to the plant roots, and causing an excessive loss of water from the sides of the large cracks. To be of greatest advantage and to be most easily carried out, fassing should be undertaken as soon as the fass will clean itself; this will generally be when the soil is already crusted and has a greyish appearance. The first fassing after sowing cotton should be begun as soon as possible, even before all the seedlings are visible, as it is essential that the young plants should not be isolated on clods and be unable to freely extend their roots. The sooner the land is fassed, the greater will be the saving of water and the longer the plant will be able to go without irrigation with its evils of diluting the plant food. The first fassing must be very light, just deep enough to cover the soil with a loose surface layer and destroy the weeds which might choke the young plants. This fassing must be carefully done from the seedlings to the top of the neighbouring ridge, so that all the soil crust is pulverised and there is no subsequent danger of the plants being torn by the hard surface. The seed holes which have not yet produced seedlings should be carefully fassed, or the crust over the seed should be dealt with by hand. Another reason for having the first fassing as early as possible, is to keep the soil in a good moist condition so that it will be possible to replant after fassing. The second fassing is usually the heaviest. Much of the soil from the opposite ridge is drawn up to the plants. This soil added to the plant side of the ridge, offers a new soil

into which the plant roots may extend. At the same time the earthing up protects the lower part of the stem and the surface roots. In the case of maize, sugar cane and potatoes, loosening the soil permits of the aerial roots or rhizomes penetrating into the soil around the plant. Fassing is discontinued when the plants are able to completely shade the soil and prevent surface evaporation and the growth of weeds.

Without weeds, the sheep would fare but poorly, the fellah would miss his salads, and the buffalo and oxen would have little green summer food. The cultivator of a few feddans must always consider the weeds as valuable fodder for his cattle, but to the large cultivator weeds are ever a loss. A weed may be defined as a plant which is growing in a place where it was not intended to be grown. Under this definition the wheat so often seen in berseem is usually a weed. All weeds are bad, because they decrease the crop in which they are growing; for where a weed is there could a plant grow, and the weed withdraws light, moisture and food from the crop. The weeds may overshadow and kill out many of the crop plants in their young stage, more especially when the crop has been sown so late, or so early as to interfere with its rapid growth or to specially favour the growth of the young weeds. Weeds like dodder and broomrape actually devour the crops on which they live; other weeds only hinder the full development of the crop in which they grow. In a properly sown crop every single weed reduces the crop, and if a few weeds are allowed in one crop their seed is usually sufficient to infest a large area of the succeeding crops.

Weeds have a further disagreeable function namely to feed the crop enemies when the crop is removed from the soil. Barefallowing should be a means of ridding the land from the enemies of the crop, but it entirely fails in this respect when it is not kept free from weeds. Land is difficult to free from weeds, but with energetic eradication for a few years the weeds can be got under fair control. Of course clean farming requires the sowing of clean seed. The most dangerous weed for choking seedlings is the "rigla," or purslane; the "lubain," or sow thistle, greatly diminishes the later cuttings of berseem; the "kabar" or fine-leaved wild mustard, "mintena" or goose-foot, and "erilla" or Allioni's mustard, occupy much of the space which should be available for the crop in which they are growing. The "neguil" or star grass is a particularly bad enemy of a badly stocked maize crop. This weed, growing with great rapidity and feeding on the rich upper layers of the soil, is able to kill many of the maize plants. Good cultivation, and sowing good clean seed at the proper season, minimises the attack of weeds.

A few of the general principles involved in the sowing and thinning of crops must be considered under the general term of cultivation. For the production of good grain, crops should be thinly stocked; for stem fibre, or tender green fodder the crop should be planted as closely as it will stand. Crops which are too closely stocked are liable to be "laid," and to be attacked by disease. As regards the quantity of seed required to sow one feddan, it is a general principle that good land requires less seed than

bad, that crops which are sown rather late or early require much seed, and that when the seed-bed is good less seed is required. On good land, the plants grow larger, and require more space, in a good seed bed the seed germinates better, early and late sown crops require more seed, either because germination is hindered, or because the plant enemies are favoured by the season of sowing.

Seeds are sown broadcast, in drills, in holes, and in special seed-beds. Most seed is required when the seed is sown broad-cast, least when it is sown in a special seed-bed. Only such plants as can be easily and safely transplanted can be sown in special seed-beds. In general, plants which develop a very deep tap-root cannot be sown in seed-beds. Seedlings are transplanted from a very dry seed-bed into flooded land. To give the transplanted seedlings a greater chance to survive some of the leaf surface may be removed and damaged roots may be cleanly cut to quicken the formation of new tissue. The cereal crops are best drilled, maize and cotton dibbled—*i.e.* sown in holes, and the forage crops sown broadcast.

Crops are sown in the land when the soil is wet, moist or dry. Berseem is sown on wet soil, wheat in moist and cotton in dry soil. Best germination is got from seed sown in moist soil except in a few special cases. Crops are sown on wet soil when the seeds are very small, and it would require exceedingly tedious cultivation to ensure their germination in moist soil. In basin land, sowing on wet soil permits of the crop being started at least ten days earlier than if the land were cultivated after drying. Crops are sown on dry soil when it would delay sowing

to too late a date if the land were watered and sowing took place in moist soil after the land had dried somewhat. When the land has been lying fallow for some time, the crop is often sown before water is applied.

When sown, seeds are covered by hand, foot, fass, mazaha, ramroum, zahaffa, plough, or cultivator. Small seeds on wet land bury themselves in the mud and require no covering except on very sandy soil. Seeds, if covered too deep, will get too much moisture and too little air; if too light a covering of soil is given, the seeds will obtain too much air and too little moisture for germination. The depth of covering most favourable to germination increases with the size and hardness of the seed, the dryness of the seed bed, the fineness of the tilth, and the porosity of the soil.

Many of the seeds which are sown in the soil fail to germinate even under the most favourable conditions. When seeds are dibbled in dry soil, and one plant is wanted per hole, far more than one seed is sown. Theoretically one seed per hole is best because less seed is required and there is less fear of one diseased seed infesting all its neighbours. Practically it is found necessary to sow 5 to 10 cotton or maize seeds per hole, because it is only the combined action of 5 to 10 seedlings that is able to pierce through the crust which rapidly forms over the seed. With bad watering, or early or late sown crops, more seed is required because the crust is harder before the seedlings appear.

When too many plants are allowed to mature, the quantity and quality of the crop is decreased, and disease is more

rampant. As far as possible the plants should be thinned to one per hole. With many crops, and on bad soil, it is usually safer to leave two plants. Crops should be thinned as soon as possible, but not before they are independent of

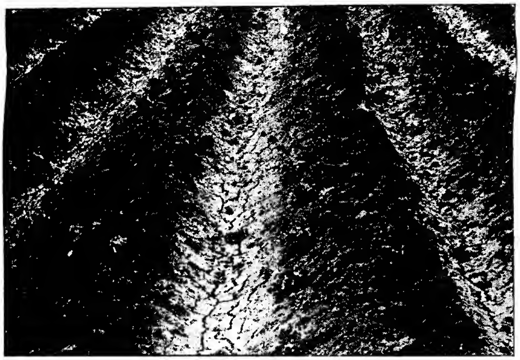

FIG. 8.—UNFASSED COTTON SEEDLINGS.
(The bunches of seedlings are seen indistinctly on the right hand slope of the central furrow just above the crusted portion).

their seedling leaves or cotyledons. The thinning should take place after fassing and just before watering, so that the irrigation water may repack the plant roots which have been disturbed. To provide green food for stock for a longish period, maize is usually very gradually thinned.

CHAPTER IV.

FARM IMPLEMENTS USED IN CULTIVATION AND HARVESTING.

THE implements in use, or suitable for use, in Egyptian agriculture may be considered under the following heads:—

1. Ploughs.
2. Cultivators, Harrows, Horse Hoes.
3. Sowing Machines, Seed Drills, Manure Distributors.
4. Rollers, Crosskills, Norwegian Harrows, Zahafa, Baitana.
5. Kassabia or Scraper, Lowatah.
6. Harvesting Machinery:—Hooks, Scythes, Reaper and Binder, Mowing Machine, Horse and Hand Rakes.
7. Thrashing Machines, Norags.
8. Grain-cleaning and Winnowing Machines.
9. Hand Implements.
10. Various.

The majority of the implements in present use in connection with Egyptian agriculture are of a decidedly primitive nature, and they appear to have been used, practically in their present form, from a very remote period. Egypt has certainly, up to the present, been backward in the introduction of improved agricultural machinery. There are two main causes of this backwardness. Firstly:—we have the aversion of the Egyptian fellah to

the introduction of any new implement and his proneness to condemn untried any new machine. He has to be gradually educated up to the use of all mechanical appliances which are profitably used in Europe and may also find a place in the agriculture of this country. Secondly :—owing to the high price of labour, farmers in Europe and America are dependent on labour-saving implements and machinery —it would in fact be absolutely impossible for them to carry on their business without the aid of modern machinery—whereas the price of labour in this country is much cheaper, and consequently from the point of view of cost of labour, there is not the same need for labour-saving machinery. From the point of view of efficiency, however, there is considerable scope for the introduction of modern implements.

The stocking of an European farm with machinery is an important item of the farmer's capital, and we may say that for each feddan under cultivation a sum of from two to three hundred piastres is required while in Egypt a sum of thirty piastres suffices.

Ploughs.—The plough has ever occupied a prominent position in agriculture. It is the most important implement at the farmer's command. The plough as used in Egypt is very primitive, and is more properly described as a one-tined cultivator than as a plough. It costs about 60 P.T. It simply stirs the soil without inverting it as modern European ploughs do. In countries where irrigation is the sole means of supplying crops with the water they require, it is necessary that in ploughing the land it should

be disturbed in level as little as possible. European ploughs which always turn the furrows to the right are unsuitable in this country as at each finish they leave an

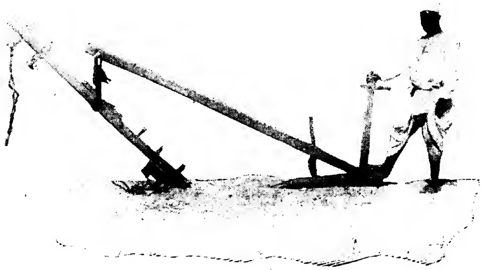

FIG. 9 *a* and 9 *b*.—EGYPTIAN OR BELADI PLOUGH.

open furrow in which water will settle. Turnwrest ploughs on the other hand, or as they are sometimes called, one-way ploughs, obviate this difficulty by turning the furrows to

the right in going and to the left in returning. A plot of land can thus be commenced and finished free from the objectionable open furrow just referred to.

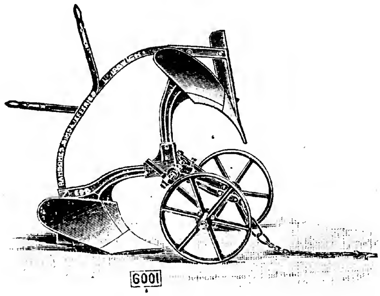

FIG. 10.—THE "NILE" PLOUGH (BALANCE PLOUGH).

Figs 10, 11 and 12 represent types of ploughs which have been found useful in this country. Fig. 10 shows a balance plough known as the "Nile" plough. It is a

one-way plough, and inverts the soil to a depth of 22 centimetres or more. On reaching the end of the furrow the plough is not turned round but simply tilted over, so that the positions of the two mould-boards are reversed and the return furrow is ploughed. It is easily drawn by a pair of bullocks and accomplishes on an average three quarters of a feddan per day. It weighs about 250 rotls and costs 750 P.T.

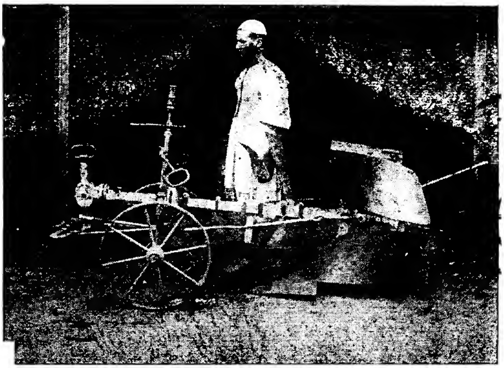

FIG. 11.—"BRABANT" PLOUGH.

Like the "Nile" plough the "Brabant" turns the furrows one way. The two mould-boards however, instead of being attached on the balance principle about the axle of the plough, are arranged to turn about an axis in the direction of the furrow. When the plough reaches the end of the furrow it is turned round, and the mould-boards are turned so that the one which made the furrow is now free in the air, and the one which was in the air now does the ploughing.

The "Brabant" weighs from 300 to 400 rotls and costs 850 to 1050 P.T. By proper adjustment of the wheels of the "Brabant" and "Nile" ploughs the depth ploughed can be regulated.

The "Koubbeh" plough is also a one-way plough but differs from the "Nile" and "Brabant" ploughs in being without wheels and in having a draft pole similar to the Egyptian or "Beladi" plough. It can be worked to a

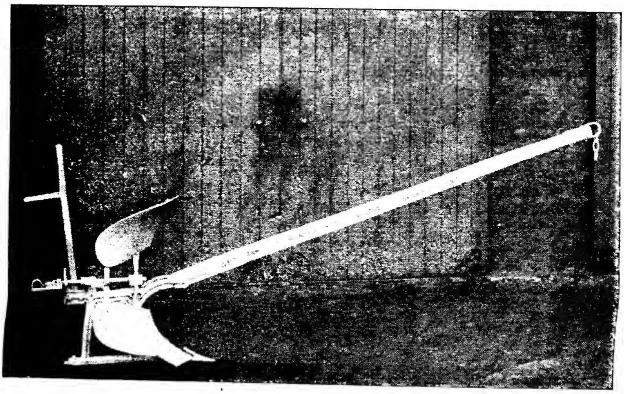

FIG. 12.—"KOUBBEH" PLOUGH (WRIGHT'S PATENT).

depth of 25 centimetres or more with a pair of bullocks. The arrangement for turning the mould-boards at the end of the furrow is extremely simple. It weighs 160 rotls and costs 600 P.T. An immense number of ploughs, differing from each other but slightly, are found upon the market, and the three just referred to may be taken as types which have been found to work satisfactorily in Egypt.

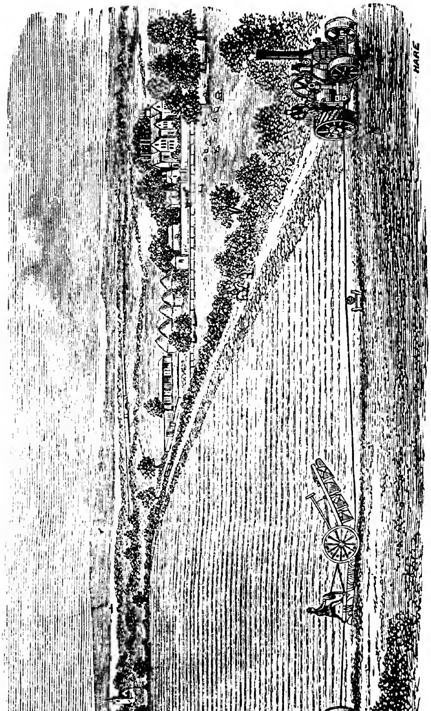

FIG. 13.—DOUBLE ENGINE STEAM PLOUGHING.

In addition to ploughs drawn by animal power, larger and heavier implements are being permanently introduced into the country. Steam ploughs have for some time been in use in Egypt but it is only recently that they have come into favour. Their price puts them entirely beyond the reach of the ordinary small cultivator, and it is only on Daïras and large properties that we may expect to see them in use. The advantages possessed by steam ploughs are the capability of breaking up the land to a much greater depth, and doing more thorough work than is possible with animal power.

The system which has found most favour is that known as the Double Engine System, in which two engines of about 16 H.P. are placed at opposite ends of the land to be ploughed, while the plough, cultivator or other implement works between them. Each engine is provided with a winding drum on which is coiled a steel rope. While one engine is hauling the plough and consequently winding in the rope, the other engine is paying out an equal length of rope. The implement is consequently drawn alternately by the two engines.

There are other systems of steam cultivation where one engine only is employed but, as they are not in use in Egypt, they need not be dealt with here. Recently motor ploughs and diggers have been placed upon the market. In this case the engine employed is a traction engine and the implement is merely drawn by the engine over the land.

An ordinary set of double-engine steam ploughing tackle costs about £ 3,300. The depth to be ploughed can be

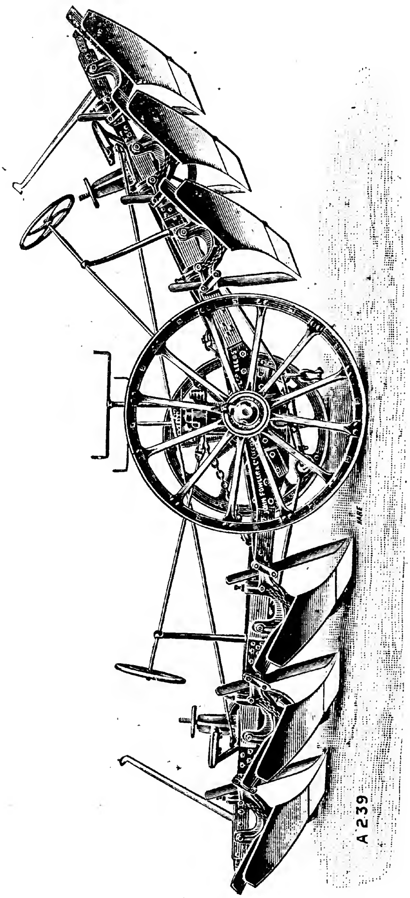

FIG. 14.—STEAM PLOUGH.

regulated according to requirement but depths up to 35 centimetres have been attained in Egypt. The amount of ploughing done per day depends upon the nature of the soil and the depth ploughed, but on average good soil, ploughed 25 to 30 centimetres deep, about ten feddans can be accomplished per day of nine working hours. Instead of the plough which inverts the soil a cultivator, which simply stirs it, is sometimes worked by this system and then from twelve to twenty feddans may be cultivated per day. Ploughs are made to turn from three to seven furrows but on average soil and working at ordinary depths four-furrow ploughs are found most satisfactory. The cultivators worked by steam power also vary in size and shape. As steam implements can be worked day and night, land can be quickly prepared for crops.

Ridging Ploughs.—The ridging plough commonly used in Egypt is the ordinary native plough with the addition of a triangular piece of wood to the body of the plough.

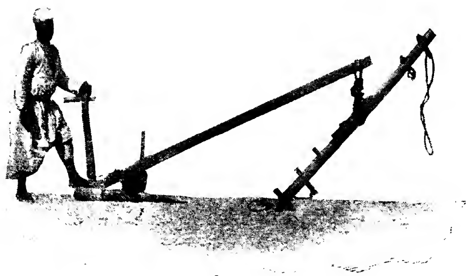

FIG. 15.—NATIVE RIDGING PLOUGH.

This displaces an equal quantity of soil to the right and left thus forming ridges suitable for the planting of cotton, sugar cane, potatoes etc.

The European ridging plough differs in construction from the ordinary plough in having two mould-boards, one on each side. The mould-boards can be adjusted to make larger or smaller ridges as required and generally the work done is superior to that of the native plough. The work on man and beast is also easier than with the native ridging plough. The European implement costs about 500 P.T.

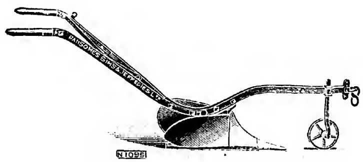

FIG. 16.—EUROPEAN RIDGING PLOUGH.

Cultivators.—The cultivator may be described as a framework resting on three wheels one of which is a swivel wheel and runs in front. To the frame is attached a number of tines which are curved so as to enter the soil in an oblique direction. Two kinds of cultivators are used, those with rigid tines and those with spring tines. The tines may vary in number from eleven to seventeen in the case of the spring-tine Cultivator.

Cultivators stir the soil to a depth of from 10 to 20 centimetres, this being regulated by a lever. They are very suitable for stirring the land after ploughing and are most useful in freeing the land from underground stems of weeds. They can also be used advantageously in Egypt for covering the seeds of wheat and barley after sowing and in preparing the land for the sowing of clover. Some

makers supply a sower for cereals which can be easily fitted to the cultivator. By this arrangement the sowing and covering of the seed can be accomplished in one operation. Three feddans of land can be cultivated per

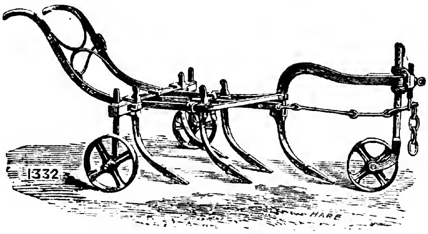

FIG. 17.—SCOTCH GRUBBER

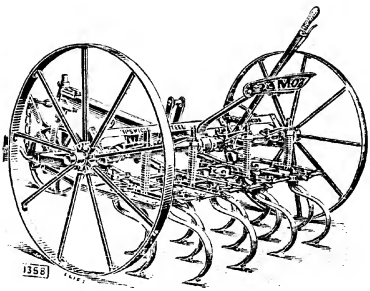

FIG. 18.—SPRING-TINE CULTIVATOR.

day with one pair of bullocks, equivalent to the work of four or five ploughs. The cost of a cultivator, exclusive of grain sower attachment, may range from ten to fifteen pounds.

Horse Hoes.—These implements are similar to the foregoing, but are much smaller, and are used principally in cultivating between the rows of cotton and sugar-cane and all crops grown on ridges. They are generally provided with five tines which stir the soil and thereby destroy weeds and prevent excessive evaporation. They are drawn by a pair of bullocks and two feddans can be hoed per day. Cost, from 300 to 350 P.T.

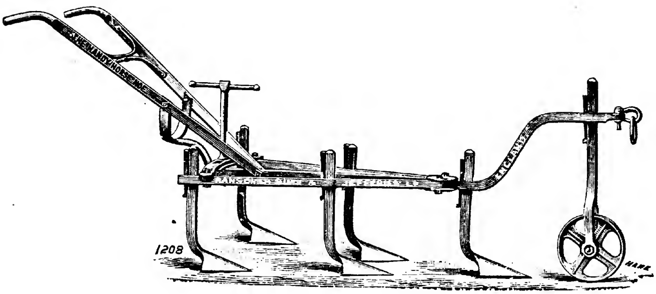

FIG. 19.—HORSE HOE.

Harrows.—These implements may be described as consisting of four longitudinal iron beams bolted together by five cross beams, on which are fixed twenty straight teeth descending vertically into the soil, these latter measuring about fifteen centimetres in length. Three harrows generally complete the set and cover a width of from two and a half to three metres. The longitudinal beams are made in zig-zag fashion so that each tooth cuts a separate track. The most suitable weight of harrow

for use on heavy land is from one hundred and eighty to two hundred and twenty pounds, and its cost is about 400 P.T.

Harrows are used for a variety of purposes. For pulverising the soil after ploughing, when it is in a friable condition, and thus rendering the surface uniform. They are also employed for covering the seed and freeing the soil from weeds. We may point out a few operations in connection with the system of Egyptian agriculture in

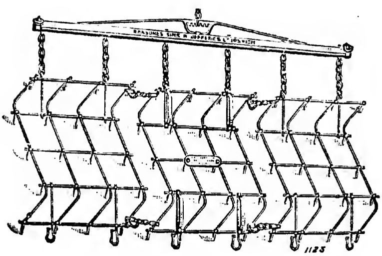

FIG. 20.—ZIG-ZAG HARROW.

which harrows may be most beneficially used. After the sowing and ploughing in of wheat and barley by the native plough we may harrow across the furrows to cover any exposed seeds. After ploughing land intended for clover, we may harrow across the direction in which it has been ploughed to make the surface uniform and render the tilth as fine as possible. The smaller the seed, the finer the tilth required. In some harrows each tooth is secured by one nut, while in others one nut secures four teeth. The fewer nuts the better as they are liable to get loose.

Sowing Implements.—The sowing of seed is one of the most important operations in connection with agriculture. This may be performed either by hand, by a broadcast sowing machine or by a seed-drill. The chief object to aim at is an even distribution of the seed. The broadcast sowing machine is composed of a triangular box from three to six metres in length and is carried on two wheels: at the bottom of this box is a revolving shaft on which

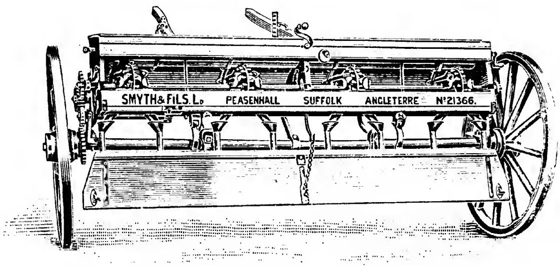

FIG. 21.—BROADCAST SOWING MACHINE.

is fixed a number of pinion wheels and opposite each wheel is an aperture which allows the exit of the seed, the flow of which can be regulated according to requirements. A machine like that shown in Fig. 21 costs from seventeen to twenty-five pounds according to the size.

The *Seed-drill* is similar in construction to the previous machine, but has scoop-wheels and, in addition, pipes connected with each aperture. These pipes convey the seed to coulters which cut a track in the soil in which the

seed is deposited and covered. The advantages claimed for seed-drills are: (*a*) equal distribution of the seed in any desired quantity, (*b*) covering of the same at a regular depth, insuring more certain germination and more regular growth, (*c*) considerable saving in seed, and (*d*) the plants are placed in rows. Seed-drills cost from

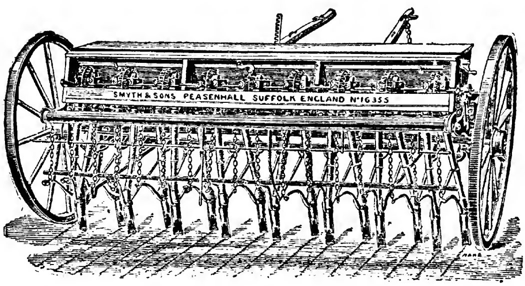

FIG. 22.—SEED-DRILL.

twenty-five to forty pounds according to the size, *i.e.*, the number of drills, which may be any number from eight to twenty.

Artificial Manure Distributors.—The principle on which these machines are constructed is similar to a broadcast sowing machine. They distribute, broadcast or in the furrow, nitrate of soda, superphosphate or any artificial manure in good condition. The quantity sown may vary from fifty pounds upwards per feddan. They cover a width of from two to three metres.

Land Rollers.—These are of various kinds, each of which is suitable for a different purpose. They may be classed as follows: (*a*) consolidating, (*b*) clod-crushers and levellers, and (*c*) Crosskill's clod-crusher. The first may be described as consisting of two or three wrought-

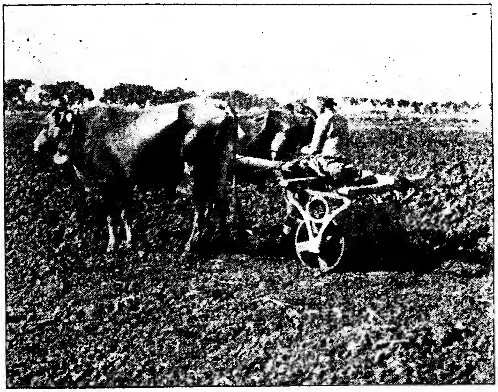

Fig. 23.—Land-Consolidating Roller.

or cast-iron cylinders about two or two and a half metres in width over all and forty to sixty centimetres in diameter.

They revolve loosely on a spindle which is attached to the frame and on which is fixed a pole or shafts. This implement is generally used to consolidate the land after sowing cereal crops, thus rendering the surface smooth. Cost, from nine to fifteen pounds.

Clod-crushers and levellers are constructed in a similar manner but of notched metal sections, from forty to eighty centimetres in diameter, which revolve on the spindle, the whole covering two metres. This is a very useful implement when the cereal crop is attacked by

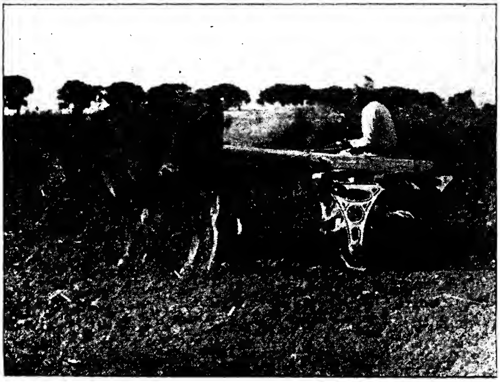

FIG. 24.—CLOD-CRUSHING ROLLER.

wire-worms and cut-worms. This generally occurs when the crop is from seven to twelve centimetres high. By the process of rolling, the land is consolidated and the ravages of the worm are to an appreciable extent checked while the crop sustains no damage. It can also be beneficially used in pulverizing the soil. Cost, from eleven to twenty pounds according to size.

Crosskill's Clod-crusher is a much heavier implement than either of the preceding, but is the same in principle except that the discs or sections are serrated and are of two sizes, one being bored much wider than the axle while each alternate one is bored to fit it exactly. This

FIG. 25.—CROSSKILL'S CLOD-CRUSHER.

arrangement permits the loose discs to eject any clods that may get jammed between the closer fitting discs. The Crosskill is principally used to pulverize hard clods but it is more desirable to plough the land when it is in a friable condition, thereby rendering it unnecessary to use such an heavy implement. Cost, fifteen to twenty pounds.

The *Norwegian Harrow* is an implement for pulverizing the soil and is of different construction to any of the previously mentioned rollers, having three axles on which are fixed spikes. When passed over the land the spikes pierce the clods and disintegrate them.

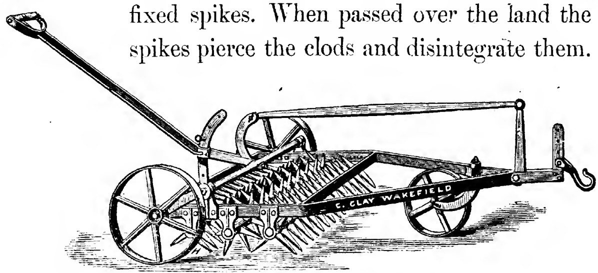

Fig. 26.—Norwegian Harrow.

In Egypt the *Zahaffa* or baulk of timber is used with some success for the purpose of attaining a fine tilth and

Fig. 27.—The Zahaffa.

making the surface more uniform. It takes the place, to some extent, of a harrow and light roller.

The *Battana* is used for the purpose of making ridges on the land for wheat, barley, maize and other crops sown on the flat. These ridges are intended to facilitate the even distribution of water when the crops are irrigated. It is generally made of wood, and consist of a flat board (or boards) ninety centimetres long, eighty-five centimetres wide at the one end and thirty centimetres at the other, with sides twenty-five centimetres deep along the two sides which are equal in length. It thus resembles

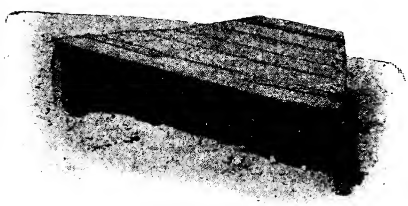

FIG. 28.—THE BATTANA.

a somewhat triangular shaped box, with the unequal ends removed and no top to it. It is drawn over the land bottom upwards and wide end first. The soil is gathered in at the wide end, and in passing out at the narrow end it is of course raised into a ridge.

Kassabia or Scraper.—The kassabia is an implement for removing soil from a higher to a lower level, and is indispensable wherever irrigation is practiced as the more level the land the more even the distribution of water over its surface. It may be described as a large wooden shovel or

scoop sixty centimetres long, ninety centimetres wide in front, and eighty behind, with sides thirty centimetres deep; and provided with two handles one hundred and twenty centimetres long. The bottom is made slightly convex

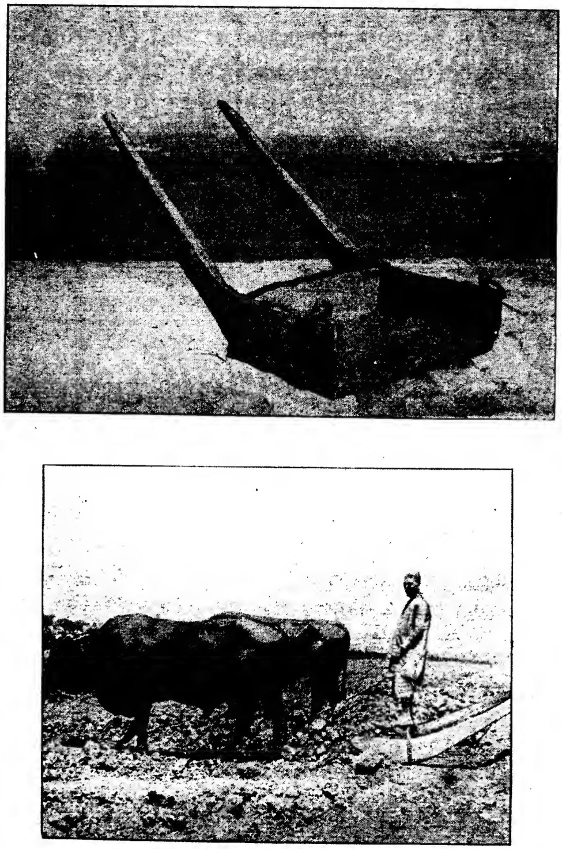

FIG. 29.—THE KASSABIA.

and the open or front part is shod with iron the more readily to scrape the earth and collect it. When drawn forward by a pair of oxen, the kassabia becomes more or less full, the contents being gradually discharged by tilting the handles, when the lower land is reached. Kassabias made of iron and fitted with wheels have been recently introduced into this country, but on practical trial they have been found cumbersome to handle and they do not discharge their contents in a satisfactory manner. Heavy scrapers of large capacity are being used for levelling in the basins of Upper Egypt. The land is previously prepared by steam ploughs and the kassabias are hauled by steam engines.

FIG. 30.—THE LOWATAH.

The *Lowatah* is used for levelling when the plot of land is practically under water. A plank of wood to which is

bolted an upright handle is drawn by two buffaloes or oxen. The high land appearing above water is scraped off and carried to the lower levels.

Harvesting Machinery.—In the harvesting of the cereal crops in Egypt, very little progress has been made in the

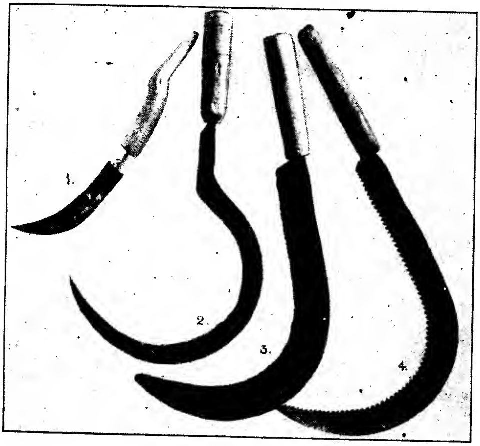

Fig. 31.—Egyptian Reaping Hooks.
1. Minshar.—2. Sharsharah.—3. and 4. Mangal.

adoption of modern machinery. The reaping hook with serrated edge is still used, but very frequently the crop is pulled by hand.

Reaping machines have been tried but with somewhat disappointing results. Some of the causes of this want of success are (*a*) the obstruction to smooth working caused by the irrigation ridges (*b*) the want of sufficient skill on the part of the average farm labourer to work such

a complicated machine as a self-binder (*c*) liability to the shedding of grain by shaking when the crop is reaped in the day time when the heat is excessive.

The low price at which cereals can be harvested by hand labour, nullifies to a great extent the advantages of harvesting machinery. Were it not so there can be no doubt that the difficulties involved in the use of self-binders would be surmounted.

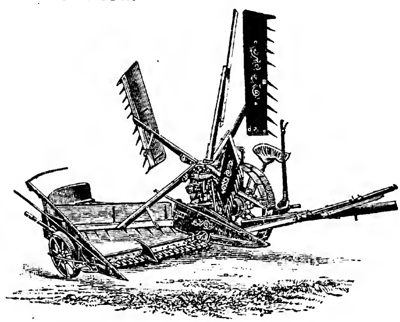

Fig. 32.—Reaping Machines.

A reaping machine consists of a main frame of cast iron, carried on two broad wheels, to which is fixed a pole for the yoking of a pair of horses or bullocks. The apparatus which performs the cutting is composed of a steel bar, about a metre and a half long, attached to the main frame. This bar is provided with a number of guards or fingers which have slots to permit of the passage of the knife to and fro. The knife is a flat steel rod to which are rivetted triangular sections having sharp edges. Motion of the knife is obtained either from a spur wheel inside the travelling wheels, or from the main axle which revolves with the travelling wheels. In both instances the speed is increased by bevelled wheels and transmitted

to a shaft running at right angles to the main axle. On the end of this shaft is fixed a crank-wheel to which is attached the connecting rod. By the reciprocating motion transmitted by the crank-wheel, the triangular sections on the knife pass from centre to centre of the fingers or guards on the fixed steel bar and thereby cut the crop. The crop when cut, falls on to a platform (as in the case of the manual delivery reaper) and when sufficient to form a sheaf is collected the platform is lowered by an attendant, riding on the machine, and the sheaf falls in the rear. Self-raking reapers perform the collecting and discharging of the sheaves automatically by means of revolving beaters and rakes, and only require one man to drive the animals. Reaping machines cost from twenty to thirty pounds.

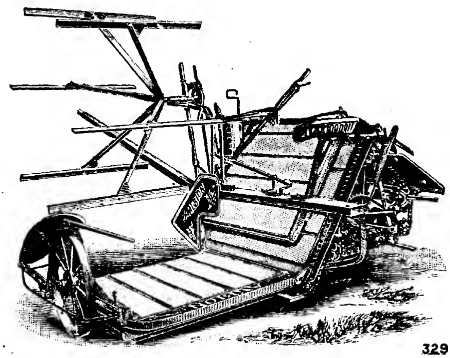

FIG. 33.—SELF-BINDER.

The *Self-binder* is a more complicated machine and consequently requires greater skill to successfully work. The points in which it differs from the above mentioned are, that when the crop is cut it falls on to a platform having a movable web or conveyor. This conveyor

carries the crop, when cut, over the main travelling wheel into the binder where it is packed into a sheaf and automatically bound with twine and ejected from the machine. Four bullocks are required for this machine. A good self-binder costs from forty to fifty pounds.

The *Mowing Machine* has no platform, the cut clover falls in the rear of the cutter-bar. A board fixed diagonally to the outermost end of the cutter-bar serves the

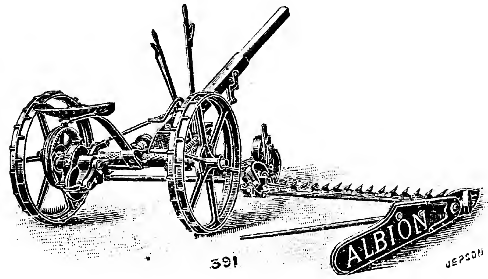

FIG. 34.—MOWING MACHINE.

double purpose of clearing a track for the next journey, and turning the cut clover into a swath. A mowing machine costs from sixteen to twenty pounds.

The *Scythe* is a most useful and simple hand implement for cutting berseem. The snath (or frame) is made of wood and has two handles. The cutting blade is about one metre long and is fixed to the snath at an angle such that the workman, when grasping the handles and bringing them close to his body, should be just able to touch the point of the blade with his outstretched left foot. The

sharpening of the blade is performed on a grindstone and, during use, the edge is kept keen by means of a whet-stone. The manner of using the scythe is as follows:—

The workman stands close to the crop to be cut with his feet about sixty centimetres apart. Grasping the handles, he swings the scythe to the right then, reversing the direction, keeping the blade level and as close to the

Fig. 35.—The Scythe.

ground as possible without coming in contact with it, he allows the point to enter the standing crop and brings the blade with a sweep in front of him thus describing a semi-circle. While swinging the scythe to his right, empty, he moves forward about thirty centimetres, equivalent to the depth of his previous cut and repeats the process. A man can cut from three-quarters to one feddan of berseem per day.

Horse-rakes are used for collecting hay into rows, and also for raking the stubble after the cereal crops have been harvested. This instrument may be described as having an axle measuring two and a half to three metres, carried by two large road-wheels. The axle carries a movable frame to which are fitted from twenty-four to twenty-eight curved steel teeth. Shafts are provided to which bullocks or horses are yoked and there is also a seat for the driver. When a sufficient quantity of hay has

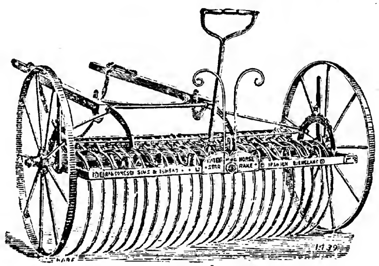

FIG. 36.—THE HORSE-RAKE.

been collected the teeth are raised by the driver pulling a lever, or as in the case of self-acting rakes, by a ratchet and pawl arrangement attached to the road-wheels. A horse-rake costs about twelve pounds.

Hand-rakes for raking together the cut berseem are made of wood. To a wooden handle one hundred and eighty centimetres long, is fixed a head measuring about seventy-five centimetres and having from twelve to fourteen teeth seven centimetres in length. This implement is used in collecting any cut hay or berseem which may be left on the ground after the bulk has been loaded into carts.

Thrashing Machines.—With a few exceptions, and those on the Daïras and extensive properties where thrashing machines are used, the norag is the only implement used for the thrashing of the various cereal crops grown in Egypt. It is very simple in construction, the more

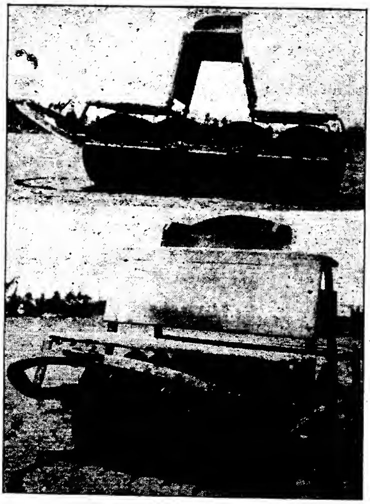

FIG. 37.—THE NORAG.

improved norags consisting of an iron frame measuring one metre eighty in length and ninety centimetres in width and carrying from four to six axles. On these axles are fixed a number of steel discs, and when the implement is drawn by a pair of oxen in a circle over the cut crop, the grain is thrashed out and the straw chopped and bruised

at the same time. This method is primitive, tedious and costly, and the sample of grain is somewhat damaged by

FIG. 38.—THRASHING WITH THE NORAG.

the droppings from the oxen. A good norag costs 600 to 800 P. T.

The method of separating the grain from the chopped

FIG. 39.—SEPARATING GRAIN AND TIBN.

straw is by throwing the mixture into the air by means of a wooden fork on a day when there is some wind. The

wind carries the chopped straw and chaff obliquely to a distance, while the heavy grain falls nearly vertically to the ground.

The cost of thrashing and winnowing a feddan of wheat by the norag may be estimated at from ninety to one hundred and twenty piastres.

The thrashing machine with straw bruising apparatus is constructed to suit the requirements of countries where the straw must be chopped and bruised as in Egypt. This machine is represented in Fig. 40 and its method of working may be described as follows: The machine is driven by means of a belt connecting the thrashing drum with the fly-wheel of an engine which is generally one of 12 H.P. The drum, from which the motions of the various parts of the machine are developed, has a speed of from nine hundred to one thousand revolutions per minute. The crop is fed into the drum which, by a beating and rubbing process, separates the grain from the ear. The straw is then carried by the shakers (which by their oscillating motion disengage any loose grain from the straw), to the cutting drum where it is chopped and thereafter falls into the bruising drum from which it is ejected on to the sifter. The latter is perforated so that any grain which may have escaped the shaking process is intercepted. Simultaneously the grain falls through the thrashing drum concave on to the riddles, which are driven by means of a cranked axle. The riddles are perforated to allow of the grain falling to the first dresser, while the chaff and short straw are carried to the bruising drum. The first dressing apparatus is fited witth a blower which, by creating a blast of air,

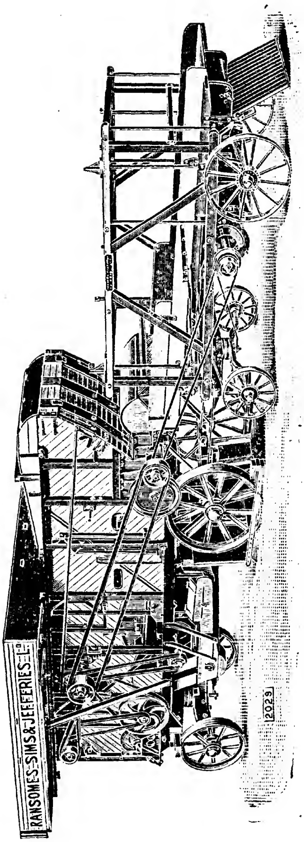

FIG. 40.—THE THRASHING MACHINE.

separates the chaff from the grain. The grain is now carried to the top of the machine by means of cup elevators on an endless belt, and is then discharged into the barley awner and polisher and thence to the second dresser. This latter consists of two perforated riddles and a blower which generates a blast of air. The grain now falls into an adjustable rotary screen where it is divided into the following grades and is discharged into sacks.

1st Consisting of small and broken grain.

2nd Second grade grain.

3rd Best quality grain.

This machine will thrash wheat, barley, beans, rice and berseem. The cost of thrashing a feddan of wheat, making an allowance of from 15 P.T. to 20 P.T. per feddan for ~~repair and depreciation of machinery, may be estimated at~~ from forty to fifty piastres. The price of a thrashing machine and portable steam engine may range from L.E. 800 to L.E. 1,000.

Grain-cleaning Machinery.—It is most important when grain is exposed for sale or is intended for seed that it should be free from impurities, true to kind, and of the best quality. For this purpose graders are used. These implements may be described as consisting of an oblong wooden frame carrying a rotary screen which revolves by turning a handle. The grain to be graded is put into a hopper from whence it runs on to a perforated riddle.

This latter separates short straw, pieces of earth and all matter larger than the grain. The grain then falls into

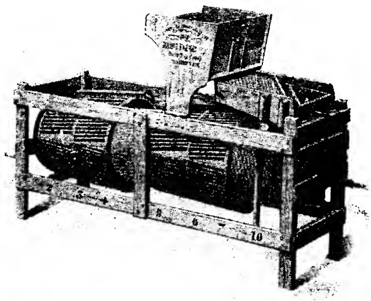

FIG. 41.—THE SEED GRADER.

the screen and is discharged into a number of boxes, placed underneath the same, each box receiving a different grade or quality of grain.

Winnowing Machines.—Unlike the preceding, this machine is supplied with fans which create a blast of air. It is used for cleaning grain, and is turned by hand. The grain is put into a hopper from which it falls on to oscillating riddles, while the chaff is blown away from the machine by the current of air created by the revolving fan. The light grain falls into a box at the end of the machine, while the heavy or best quality grain falls through the riddles, and by passing down an inclined sieve the small seeds of weeds, etc., are separated, and the operation is

complete. Winnowing machines cost from 750 P.T. to 1,200 P.T. according to size.

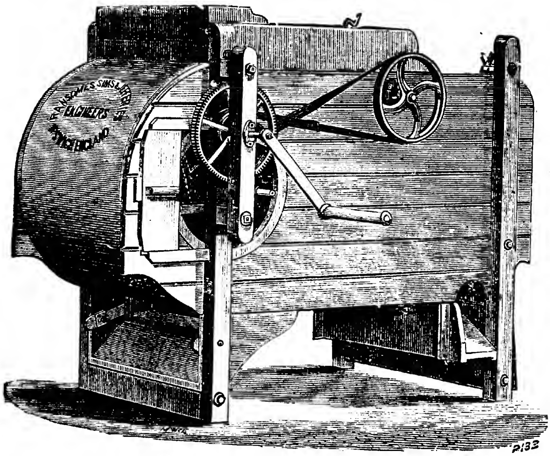

FIG. 12.—WINNOWING MACHINE.

Hand Implements are not numerous. The Fass is the most useful and it may be described as a heavy hand hoe, shaped like an adze. The Maazaka is used instead of the fass when working in wet mud. It is lighter and not so deep but longer faced. The face is curved inwards so that the mud does not cling to it so much as if it were straight.

The Midrah is a wooden five-pronged fork having a handle a metre and a half long. It is used for throwing into the air the tibn and grain after the crop has been thrashed by the norag. It is really a primitive process of winnowing, see Fig. 39.

FIG. 13.—THE FASS AND THE MAAZAKA.

FIG. 14.—THE MIDRAH.

Hand grain-cleaning utensils consist of circular riddles of varying meshes, sieves and menofahs. The latter is a

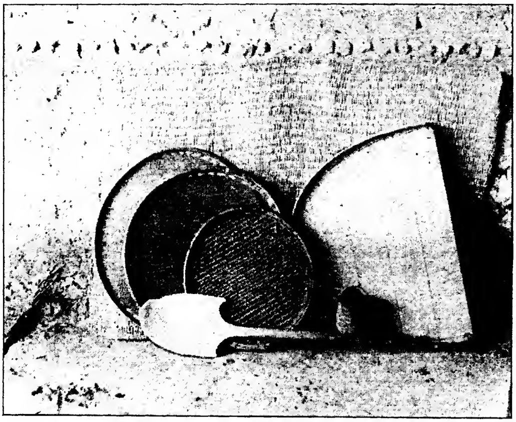

FIG. 45.—GRAIN-CLEANING IMPLEMENTS.

semicircular riddle made entirely of wood, and is used to separate heavy foreign matter from the grain.

Maize Shellers are found to be of great utility. The cobs are fed into the machine and pass between revolving spiked discs which disintegrate the grain from the cobs. Small machines worked by hand may be got for 600 P. T. while large ones, shelling seventy ardebs per hour and requiring 6 H. P. to drive them, cost L. E. 120.

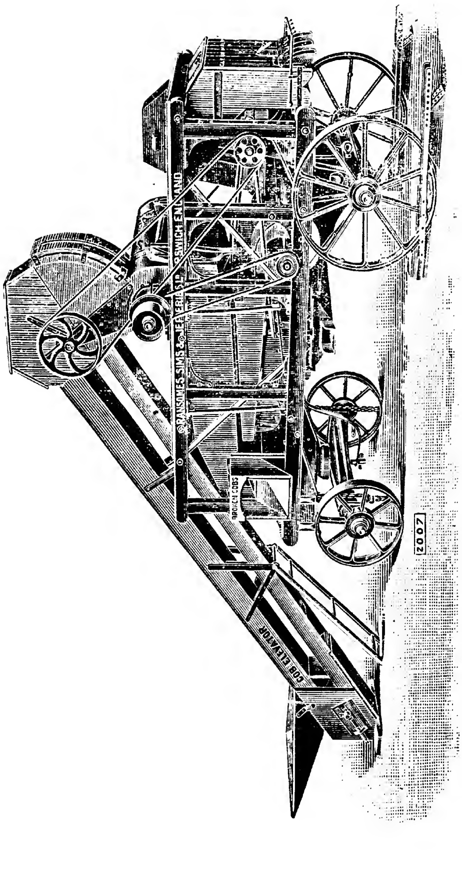

Fig. 46.—Maize Sheller.

Corn Bruisers.—These may be beneficially employed where horses and cattle are fed on uncooked barley as, by the bruising process, the grain is broken and therefore more easily digested. These machines are very simple and consist of two plain or grooved steel rollers which revolve

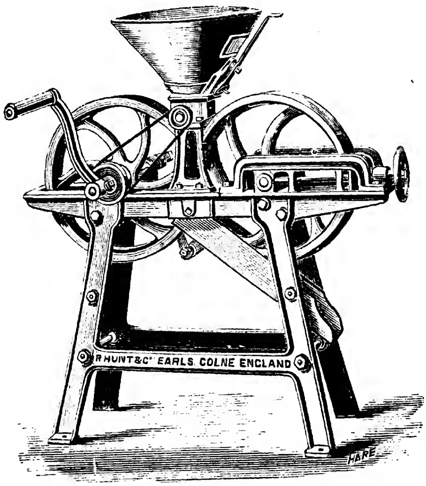

FIG. 17.—SMOOTH ROLLER BRUISING MILL.

towards each other, the distance between the rollers being regulated by a hand-screw so as to give greater or less pressure. The grain is fed into a hopper from which it falls between the rollers and is crushed.

Maize and Bean Kibblers are machines similar to the preceding with the exception that, instead of two rollers they are fitted with a grooved roller working against a

corrugated concave, the position of which is adjustable. The maize or beans passing between are split or ground into meal as desired.

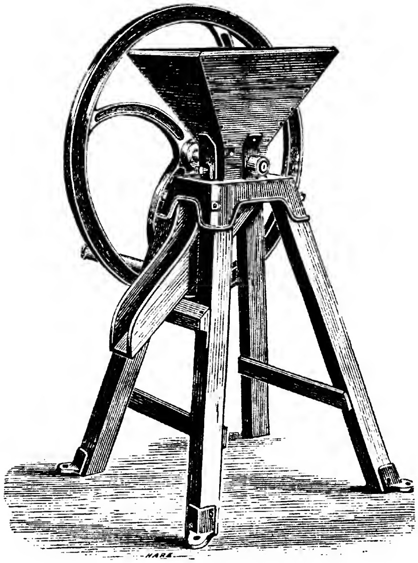

FIG. 48.—MAIZE AND BEAN KIBBLER.

Corn bruisers and bean kibblers are got of all sizes, for both hand and steam power. They cost according to size from 400 P. T. to L. E. 20.

CHAPTER V.

IRRIGATION AND DRAINAGE.

Water being an absolute necessity of plant life must be supplied, in an almost rainless country like Egypt, by artificial means. It is needed: 1st, directly to increase the growth of the plant of whose weight it forms a large proportion, 2nd, to form a solvent of the otherwise unassimilable plant food in the soil, 3rd, to supply the very large amount of moisture exhaled or transpired by the plant, 4th, to fit the soil for those bacterial organisms which exercise so large an influence on plant life. Water does more than meet these physiological demands of the plant, for it also brings a large amount of plant food either in solution, or in suspension in the form of the rich red silt of the Nile in flood (see p. 25).

There are two systems of irrigation in Egypt, the Basin system of Upper Egypt, and the Canal system of Lower Egypt.

The basin system seeks to utilize the Nile water only during flood. The whole country is divided into large blocks surrounded by high strong earth banks, often pitched with stone to resist wave action. There were till recently over 200 basins, with a gross area of 1,435,000 feddans, which is an average of 7,000 feddans, but the individual areas vary greatly from some small ones of 700 feddans to the huge Koshesha Basin of 75,400 feddans. When the Nile rises, these basins are filled to a depth of 1 to 2·5 metres

with the red water rich in silt. The value of basin land depends on the amount of silt deposited, and consequently basins or parts of basins which are nearest the source of supply are most valuable as they receive most silt. Beginning with an appreciable rise in July, the Nile continues its rise in August till it attains the maximum which is maintained during the first ten days of September, after which it begins to fall less rapidly than it rose. The basins are grouped into systems which are fed by large canals taking water directly from the Nile.

The objects of the Irrigation Engineers are to fill the basins as early as possible and to a sufficient depth with rich silt-laden water, to leave the water 30-40 days to deposit its silt and then to drain it back into the Nile. The cultivators follow the retreating water, as it lays bare the basins, with their sowing of winter crops. If the *Nile flood is a poor one there is difficulty in filling the* basins. In former years under such circumstances large areas remained without water, entailing most severe loss on cultivators, and remission of land-tax by the Government. Much has been done in the past fifteen years by remodelling and improving the basin system to greatly mitigate the evils of a low flood, and this so successfully that even in recent bad floods the unirrigated areas have been trifling. Instead of draining the basins directly into the Nile, by a judicious arrangement of canals the water from the higher basins, which were first filled, is passed into the lower basins which had only received partial filling and thus the latter in bad years can be saved from drought, although they may only receive clear water from which the upper basins have abstracted the silt.

A very high flood and a slow fall of the Nile retards the draining of the basins, and the sowing of crops may be unduly late.

The whole working of the basin system, filling and emptying them, and passing water from higher to lower ones entails most caretul calculation and supervision. This work is entirely in the hands of the Irrigation Department and only the results concern the agriculturist.

Under the basin system, only winter crops can be grown, such as wheat, barley, beans, vetches. There is no agricultural work to be done between harvest and flood. Repairs of basin banks, and clearances of canals occupy the population, of whom, however, many seek work in Lower Egypt. Others are employed in laboriously raising water by Shadoofs to irrigate small patches of summer cultivation on the banks of the Nile or adjoining canals.

Till now, the basin system has been the best method of utilising the Nile flood in Upper Egypt, but on economic grounds it will disappear, or at least under gogreat modification.

The whole of Upper Egypt is not solely on the basin system and dependent on winter crops only. There are now 886,900 feddans cultivated during summer in sugar cane, cotton and durah, and when the Nile reservoir at Assouan has been heightened the area receiving perennial irrigation will be greatly increased and the basin system will practically disappear. Up to the end of 1907, the total area of basin land converted to perennial irrigation is 322,961 feddans; this cost L.E. 3,050,373. Instead of completely abolishing the basin system it would be more

judicious from an agricultural point of view to so divide the basins into two that summer cultivation could be confined to one half in alternate years, whilst the other half could be flooded, as is now done, but in alternate years. In this way all the land would have a thorough renovation with rich Nile mud every second year, and the noted fertility of Upper Egypt would be maintained.

Lower Egypt has now no basins, although in ancient times the basin system was universal and survived in certain parts till a century ago. Irrigation in Lower Egypt is effected entirely by canals. In flood numerous canals take water directly from the Nile, but in summer, when the supply is limited, every drop of water is arrested by the Barrage, 12 miles north of Cairo, and there distributed by three great main canals to their respective circles of irrigation. Each of these great canals is soon divided into smaller ones, which in their turn are again subdivided till there is a system resembling the distribution of blood to the body, and every part of Lower Egypt, even to the extremities, receives its due quota of water. For eight months of the year, September to April, water is abundant, but from May to August the scarcity necessitates strict regulation by a system of rotations according to which, canals or sections of canals receive water for a certain number of days and no water during so many more days. The strigency of rotation varies with circumstances. It is extreme when there are 6 days water and 18 days none. It would be quite convenient for the cultivator to receive water six days in each alternate week, leaving one day each week when no water would be taken by any one, and canals would fill up to the benefit of distant users.

The perennial supply of water available in Lower Egypt enables the agriculturist to sow half his land in summer

crop, and all of it in winter crop. Theoretically he should have one third in summer crop of rice or cotton, one sixth under maize which is a Nili or flood crop, and the whole area under winter crops of wheat, barley, beans, and berseem.

In favoured localities that system is quite disregarded, for half the land is under cotton, more than a third under maize sown as a summer crop, and the area of the winter crops is only restricted by the cultivator having so little summer fallow that he cannot prepare land for winter crops till he is clear of the cotton and maize.

The completion of the great Nile dam at Assouan and the filling of the reservoir had very marked effects on Egyptian agriculture. The storage capacity of the reservoir was 1000 million metres cube, equal to a supply of 10 million metres during the 100 days of summer scarcity. The dam is now being hightened to hold up another 7 metres depth of water, and the capacity of the reservoir will be doubled. This is added to the usual summer discharge. The mean of 20 years' discharge at Assouan during the months of April, May, and June is 45 million metres daily. The increased supply is therefore only 44 per cent. and a good deal of that is to be used in Upper Egypt on lands which have not hitherto had perennial water. There have, however, been years when the daily discharge at Assouan has dropped below 20 million cubic metres in the month of May, and the Nile dam will now prevent anything like the dangerous scarcity which occurred in such years.

Whilst the Assouan dam has for its object the storage of water, there are other barrages meant only for distribution. These by raising artificially the level of the river permit the great canals to be filled. In Upper Egypt

there is the Esneh barrage under construction, and the Assiout barrage which, closed in a bad flood, saved an enormous area of basin land from imperfect filling.

The Barrage 12 miles below Cairo sends a supply down the three great canals which irrigate the whole Delta.

The Zifta barrage is also an important work. The early red water of the flood was largely wasted into the sea down the Damietta and Rosetta branches of the Nile. The discharge at Cairo, which is only 550 cubic metres per second about the 5th of July, is 1000 cubic metres by the 20th and 1800 cubic metres by the 31st of that month. The Zifta barrage arrests and distributes that early flood passing down the Damietta branch, and a similar barrage in the Rosetta branch will perform the same function there.

If water can be had by the 15th of July for maize and flood rice sowing, Government would be perfectly justified in publishing a decree permanently forbidding all rice and maize cultivation before that date. These are properly Nili crops, but of recent years the abuse has arisen of using for these other crops' water, which should be devoted to cotton only. The Nile reservoir has after all a limited capacity, and other storage schemes, either in the great Central African lakes, in Lake Tsana, or in the bed of the White Nile itself are under consideration. But if the water is not unnecessarily used for other crops it will suffice for all the cotton which can be grown for some years to come.

Drainage is almost as necessary as irrigation, and that for various reasons. It permits the passage of air into the soil to oxidise and break up plant food, and to render harmful matters innocuous. It allows the filtering through of fresh water to remove noxious salts. It facilitates the penetration of plant roots, and thus increases their range

in search of food. It dries land and makes it workable, and also makes the soil warmer. It lowers the water table, which unless kept well below the surface is simply a source from which capillarity draws water up to the surface of the land to be evaporated by the hot sun, leaving a salt incrustation inimical to all vegetable life. Again, beneficent bacterial life flourishes better in well drained soil and agricultural science is now recognising the new doctrine that the biological conditions of a soil are just as important as the chemical and physical conditions.

It is only in the last twenty years that drainage has received due attention from the Irrigation Department. Between 1885 and 1905 there were constructed 4185 kilometres of drains at a cost of L.E. 1,468,187. Previous to the former date very few drains existed.

In Upper Egypt, the Nile itself forms the great drain. At flood the whole land is under water for a short time, but the excess is quickly drained off the surface. As the river falls the water table gradually sinks, but not so quickly as to get away from the roots of the plant, nor so slowly as to become sour and stagnant and injure them. So long as this beautiful provision of nature is not interfered with, Upper Egypt will not require drainage, except for low lands far from the river and cut off from it by perennial canals. For lands so situated provision is now being made by Government.

In Lower Egypt, however, far greater distances from the river prevail, the river has not the same extremes of rise and fall, and perennial canals exist everywhere. Consequently an enormous number of drains have been dug all over Lower Egypt. They generally occupy a position midway between two large canals which between them

enclose a considerable area of land liable to become water-logged. A small infiltration drain alongside a large high level canal would in many cases save adjacent land from deterioration caused by waterlogging. The system of making a central drain between two canals is meant to cure the evil of waterlogging. Infiltration drains alongside the canals would prevent the evil.

All large irrigation and drainage works in Egypt are undertaken by the Irrigation Department of the Ministry of Public Works, and it is therefore only necessary to consider such minor works as may fall to the agriculturist to execute for himself. He will rarely have to deal with larger blocks of land than those containing a few thousand feddans.

The quantity of water required varies according to crop, soil, and time of year. Cotton in its early stage, if sown on soil retentive of moisture, and which has been well watered, may go 40 or even 50 days without a watering, but on other land, salty or readily parting with moisture, it would not go half the time. In later stages of growth the weather is hotter and the greater leaf development causes greater exhalation of moisture so that irrigations are necessarily more frequent. Berseem in winter requires only one watering after each cutting, once in 40 days. When hot khamseen winds occur in April, berseem would be forced into flower and dried but for an extra irrigation. Cereals require about two waterings during the period of their growth which is in winter. Whilst then different crops, and the same crop at different stages of development, vary greatly in demands for irrigation, still the duty of water can be calculated when a sufficiently large area is considered.

For summer crops in Upper Egypt the calculation for

the year 1901 was 29·6 cubic metres per feddan per 24 hours. In Lower Egypt, for the whole area, including cultivable land uncropped, the calculation was 9 cubic metres per feddan for the year 1900. But that was an extremely bad low Nile, and no rice was grown. In 1901 when rice was grown the calculation rose to 11·67 cubic metres. For the area cultivated with summer crop, exclusive of rice, it may be accepted that 25 cubic metres per feddan per 24 hours is sufficient. For rice, it is assumed that 40 cubic metres per feddan per 24 hours is needed, but this is admittedly an underestimate. During the first week or 10 days of its growth rice is flooded to a depth of 5 centimetres, generally more. The water is run off each evening, and the field filled up next morning. The daily supply during the first 10 days is therefore 200-300 cubic metres. Afterwards, when the rice plant is stronger a current is kept running through the field and the quantity used is unknown.

The calculation of 25 cubic metres per feddan per 24 hours for irrigation, other than of rice, can be applied to large Government canals, but for small agricultural canals and irrigation channels the carrying capacity must greatly exceed this rate. On a large estate, it may be necessary to sow say 50 feddans of berseem in one plot of summer fallow deeply cracked and very dry. If the little channel only carried $25 \times 50 = 1250$ cubic metres it would irrigate 3 feddans a day of such land and the plot would take 17 days to sow. It should be done in about 3 days.

When dealing with a block of 500 feddans we do not require to sow the whole area at once; it is probably under various crops, and only a part requires sowing at one time.

Taking a still larger area such as 5000 feddans the canal

capacity need not greatly exceed 25 cubic metres per feddan per 24 hours. It will probably run nearly the whole 24 hours, and only be shut down a few hours during the night. The little canal for 50 feddans must do its work in daylight usually, although during rotations and in moonlight the fellaheen attend to the water throughout the night.

The following diagrams show types of agricultural canals.

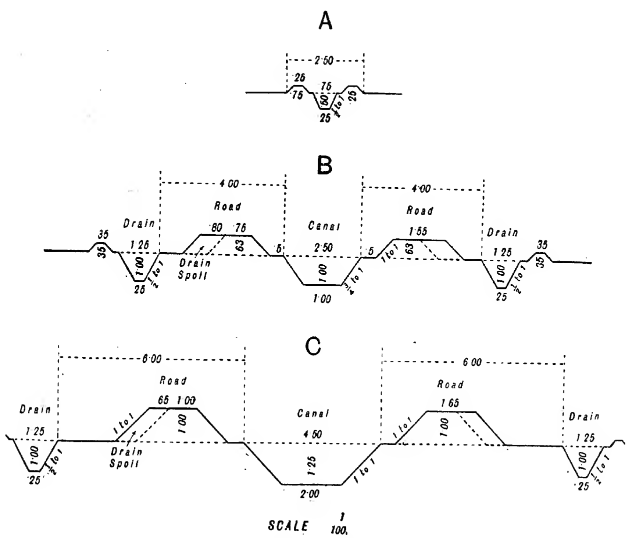

FIG. 49.—DIAGRAMS SHOWING TYPES OF AGRICULTURAL CANALS.
A for 50, B for 500, C for 5000 feddans

These canals embody the results of much practical experience. In canal A, the banks are too small and weak, but a little channel like that is constantly being cleaned and the banks gradually strengthened. It is sometimes

better to dig a larger channel in order to get more earth for banks, and afterwards it can be allowed to silt up and reduce its sectional area to proper dimensions.

Slopes of banks must be ruled by the nature of the soil. Drains not carrying much water, and the smaller canals not running constantly may have steeper slopes, for, if a bank does slip in, the obstruction is easily cleared. With larger canals and drains risks must not be incurred, and safe slopes should be given from the first.

Roads are not made to full width at first, but space is left for widening them with soil thrown out in annual clearances. Besides, banks sink and broaden out and when sufficient width has been attained the fellaheen may be allowed to remove the canal silt clearances to top dress their fields, and this they very readily do.

It will be noted that in calculating sectional area, only the excavated area is taken, although canals usually carry water above ground level. But the berm of the canal soon grows weeds which obstruct the current, and the area of channel above the berm has no carrying capacity. The central area above ground level has carrying capacity but is set against irregularities and obstructions which soon appear in the channel.

Canals are dug of sufficient section to afford soil for making banks, which should be strong enough to keep in the water, and wide enough for paths or roads to give easy access to the fields. All canals which hold water permanently up to ground level must have infiltration drains to intercept the leakage, which would otherwise waterlog the soil alongside the canal and greatly deteriorate

the crops. The soil excavated is almost all used for increasing the width of canal banks and only a little is required for the drain bank.

On no account should canal banks be cut to draw off water for irrigation purposes. Earthenware pipes should be used and on the larger canals small regulators of stone or brick masonry should be built, fitted with a sluice gate opened and closed by an iron screw. The screw should have lathe-cut threads, and never be less than one and a half inches in diameter. The waterway of regulators should not be less than one quarter of the waterway of the canals which they supply.

Canals should be cleared annually of all silt deposit. January is a suitable month for this work as little irrigation is required by crops, and the canals can be closed. If a canal is not carrying sufficient water, opportunity is taken during the annual clearance of deepening the tail-end. A canal 2,500 metres long supplying eight different properties gave a very poor supply to the last one at the tail end. By deepening it 25 centimetres at the first year's clearance and again another 25 centimetres the second year, it had such a slope that water reached the last property freely. Agricultural canals should have a slope of at least ten centimetres per kilometre $=\frac{1}{10000}$ and the smaller one at least twenty centimetres per kilometre $=\frac{1}{5000}$.

Planting canes—"Boos"—along small canal banks is very advantageous. Their roots strengthen the banks greatly whilst the canes are useful for roofing huts and cattle sheds, and for fencing vegetable plots. They grow quickly and occupy the banks but do not grow in the water and

check the flow, and they prevent the growth of weeds which soon choke a canal.

Drains should be nearly the same size as canals for corresponding areas, although only one third of the irrigation water used finally reaches the drains. The rest of the water is lost by evaporation, absorption in the soil, and exhalation by vegetation.

Whilst a canal runs full, a drain should carry only a little water in the bottom so that the water surface should be nearly a metre below the ground surface. It is only when the water in drains is at a low level that the water table in the soil is kept down and capillarity prevented from causing salt incrustation on the surface of the ground. It is for these reasons that drains are made large. A drain running full whilst removing temporary excess of water is not fulfilling its true function of keeping down the water table.

Drains require only small banks, unless the banks are needed for roads, and excess soil may be spread over the adjoining land. They should, equally with canals, receive a thorough annual clearance, but the silt deposit should be very little. No red water should ever be seen in drains as all silt should have been deposited on the fields and only the clear effluent run off. Drains should have a clear course throughout their entire length, unobstructed by any pipes or syphons. Where pipes are absolutely necessary, they should be of large section, at least one half the sectional area of the drain, to prevent heading up of water in the drain. It is better to syphon a canal over a drain, rather than to carry a drain by a pipe below a canal or road.

In many parts of Egypt agricultural drains do not exist. In these places water is generally lifted by sakieh or pump and no excess is used, whilst the land is high enough to have a low water table to which the irrigation water sinks. But as Government have now a vast system of main drains all over the country, it would be wise if proprietors made their own agricultural drains to join up with those main drains.

Drains are subject to great abuse. It is a common sight during high Nile to see drains running full cf red water undistinguishable from canals. The proximity of a drain tempts the fellaheen to run into it from a canal all the water they do not need, instead of closing the canal at its head. This abuse of drains and waste of water should be more effectually checked by adequate supervision and substantial fine or imprisonment.

Drainage is always effected in Egypt by means of open drains. Where a sufficiently low outfall can be had, the minimum depth should be one metre, and if a greater depth can be attained so much the better. Depth of drain increases depth of feeding ground for the plant.

Drained land, whilst losing the stagnant water of saturation, is more retentive of moisture than undrained land, and better able to resist drought.

The soil of Egypt will make canal banks without being subjected to the process of puddling *i. e.* kneading it up with water. It is therefore by no means a porous soil, and yet drains one metre deep and fifty metres apart work well and draw from the distance of twenty-five metres, and this too where the object in view is not merely

drainage but the washing of fairly impervious salt land by filtering fresh water through it. On cultivated land, free from salt, drains 200-300 metres apart would be found to be all that is needed to keep down the water table. Over very large areas in Egypt drains are unknown and yet the most fertile land in the world can be found in these tracts.

The English system of field draining by means of underground earthenware pipes is so absolutely opposed to what is deemed necessary in Egypt that a description is desirable. In England drains are dug about one metre deep, at distances varying from six to fifteen metres apart, and along the bottom of these cylindrical pipes are laid, usually of 5 centimetres bore, and the trench is then filled in. These small pipe drains are led into a larger main pipe drain running along the lowest part of the land till it finds a convenient outlet. The cost of draining in this way varies from Lst. 5 to Lst. 10 per feddan. Without this elaborate and costly drainage much land in England could not produce good crops, and would only grow the coarsest and most worthless grasses.

Pipe draining has not been adopted in Egypt, and till it receives a proper trial it is an open question if the advantages would be found to repay the cost.

The State Domains Administration made some extremely interesting and valuable experiments at Bechbiche, Garbieh, which are described in Vol. V. No. 3 of the Journal of the Khedivial Agricultural Society and the School of Agriculture. Washing salt land was tried on three equal plots of 27 feddans, first by colmatage, second

by filtration into open drains, third by filtration into pipe drains. The first was unsatisfactory, the second good and costing L.E. 4 per feddan and the third better still but costing L.E. 12·8 a sum out of proportion to the extra benefit.

Pipes in Egypt are much too dear, although if a demand arose they could probably be made at a price which would warrant their use. In England pipes 7½ centimetres bore cost L.E. 2 for a length of 300 metres. Where a small drain already exists, it and its banks have a width of 4 metres. If pipes were laid in the drain at a cost including transport and laying of L.E. 3 then $300 \times 4 = 1200$ square metres of land would be recovered. If the land is worth L.E. 42 per feddan, and on land of less value it would hardly be worth while experimenting, the value of the recovered land is L.E. 12 and the cost has been L.E. 3. The annual clearing of the open drain would be saved, and a source of danger to animals would be removed. Damage and loss of live stock frequently occur by animals falling into open drains.

A mole drain plough has been made by Messrs. Fowler & Co. which they claim has done work which remained satisfactory after forty years' test. There is a frame carrying a strong share to which is attached a pointed iron solid cylinder. This cylinder being drawn through the soil at the depth of one metre leaves behind it a bore hole which serves as a drain. By attaching a wire rope on which pipes are strung these can be drawn into the bore, but in clay soil the pipes can be dispensed with. It requires a ploughing engine of at least 16 H. P. to work

the mole drain plough and even then the cable is given double purchase by passing it round a pulley on the plough and bringing the end back for attachment to the hind wheel of the engine. With the level land of Egypt, and the plastic nature of the soil, which would probably give a durable bore, an experiment by some of the proprietors owning ploughing engines is well worth trial. It would be a very cheap method of draining.

Maize and cotton stalks tied in bundles have been laid in the bottoms of open drains and then covered in with earth. For short lengths of drain, this might serve but it would not make either a good or a durable drain.

CHAPTER VI.

FARM IMPLEMENTS OF IRRIGATION.

THE level of land surface in Egypt represents the maximum height at which flood Niles have deposited silt, and it follows that after the flood has passed and the river gradually sinks below the level of the land, the water must be lifted, if irrigation is to be accomplished. This necessity produced the Shadoof which figures on some of the ancient temples of Egypt, and more than 2000 years ago Archimedes invented his screw for irrigation in this country.

In Upper Egypt the difference between high and low Nile is 7 to 8 metres, in northern Lower Egypt it is not more than 1 metre. The varied conditions of height of lift, and quantity of water required, have given rise to many types of water-lifting machines, ranging from the humble shadoof lifting its 100 cubic metres per day to huge steam-driven pump lifting 350 cubic metres per minute. All these machines have their special uses, and in adopting any particular type careful consideration of the local conditions is necessary.

All water lifts, of whatever nature, must be reduced to one common standard of Water Horse Power, W.H.P., *i.e.*, the actual quantity of water lifted a certain height.

French "Horse Power" is 4,500 kilogrametres per minute.

British "Horse Power" of 33,000 foot-pounds equals 4,554 kilogrametres, only $1\frac{1}{4}\%$ more.

1 W.H.P. equals	1	metre	cube	water	raised	4·50	m.
	1·5	..	..	..	..	3·00	..
	3·0	..	..	..	..	1·50	..
	4·5	..	..	..	..	1·00	..

The metres cube of water raised multiplied by the lift in metres and divided by 4·5 give the W.H.P. of a machine. Comparison can then be made between machines of different type.

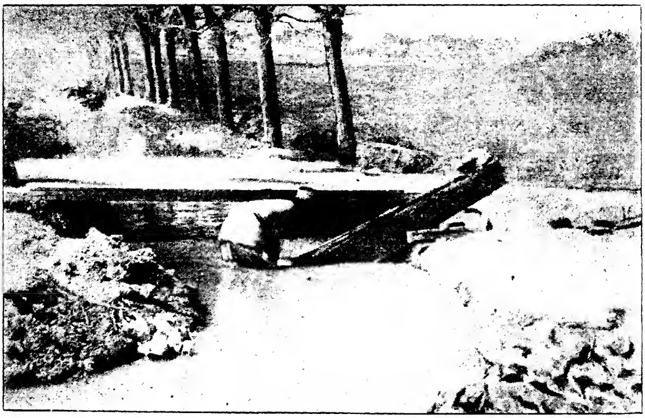

Fig. 50.—The Badala.

The *Badala* or *Waboor* is a machine for lifting a small quantity of water not more than 50 m. high by means of one man. Three boards 2·50 to 3·00 m. long by ·20 broad are formed into a long trough closed at one end and open

at the top. The open discharge end is fixed to a cross-bar pivoted on two posts driven into the ground. A cross-piece of wood forms a handle at the closed end. A man seizing this handle plunges the wooden trough into the water to fill it, then raising it up till the closed end is above the level of the discharge end he pours the water in the trough into the irrigating channel. A wooden trough of this sort costs about 20 P.T., is fixed by merely driving two small posts into the ground, and is worked by one man. The end of the trough which is dipped into the water is frequently made somewhat wider than the end from which the water is discharged. When full of water it is heavy to lift and is often partly counterpoised by stones placed over the open end.

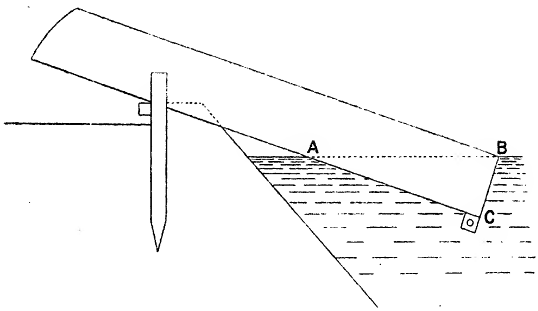

Fig. 51.

The quantity of water raised is represented by ABC the immersed section of the trough which is generally about $\frac{1}{3}$ of its length. In this case the discharge would be 20 litres

per dip, and a man could dip about 6 times per minute, lifting 7 metres per hour if working continuously. Arm work is fatiguing, as much effort being needed to force the trough into the water as to raise it after it has left the surface. By making a trap door in the bottom of the opening upwards and hinged with a piece of leather the effort of forcing down the trough into the water to overcome the resistance of displacement is saved.

A man lifting weight with his arms can only exert 20 kilog. effort but using the weight of his body his effort is 60 kilog. The writer made a pair of troughs with posts and cross-bar to give secure support to a man who by treading alternately on each trough exerted the whole weight of his body. The troughs were made larger, were fitted with traps, and with counterpoises to raise and discharge them. The native Egyptian is relatively much stronger in his legs than in his arms and his average weight is quite 60 kilograms. He could go on a much longer time working this water treadmill and lifting very much more water than he could when standing in water up to his middle and working with his arms. The apparatus, however, is only good for a lift of 25 to 50 centimetres.

Nattala.—Is the simplest of all water lifts, being nothing more than a straw mat basket, closely plaited, with four cords attached. Two men standing well above the surface of the water and opposite to each other take a pair of cords each, swing the basket out over the water, and on the return swing dip it down, and scoop up a fill of water which they discharge over a little bank into the irrigating

channel. Elaboration of this very simple method stops short when a leather skin basin is used as the dipper and when two small mud pillars have been built behind the men to rest their buttocks on and prevent their falling back when leaning outwards after discharging the dipper.

Stooping forward and lowering his hands, then swinging them up to the level of his head a man has a range

FIG. 53.—THE NATTALA.

of arm 1·25 m. and this is the extreme height for judicious use of the nattala whilst 1 metre is a better height for it. About 5 metres per hour is the assumed discharge by a nattala.

Shadoof.—Two posts or earth pillars are erected with a cross-piece on which is pivoted a long lever. On the short arm of the lever is fixed a stone, or large ball of mud, as a

counterpoise to a rod and dipper hanging from the long arm. The dipper is usually a skin bag with wooden rim about 0·45 m. dia. × 0·25 m. deep, with a capacity of about 20 litres. A man seizes the vertical rod, taking a good high catch, pulls it down and fills the dipper which, on his releasing his hold, is carried up full by the counterpoise

FIG. 52.—THE SHADOOF.

and when it reaches the height of the man's breast he tips the water out into the channel.

From his high catch to the bottom of his stoop a man has a range of 1·75 m. and on that lift he would not need to change his hold on the rod, and would make 10 strokes per minute. But the vertical rod is 3-4 metre long, and

he pulls it down hand over hand, giving the shadoof a lift of 3 metres, in which case the number of strokes would not exceed 5 per min. In ordinary work the lift is 2·00–2·50, and the strokes 7 per minute. In upper Egypt it is very common to see three shadoofs at work, one discharging to the other to attain a lift of 6 or 7 metres.

The capacity of a shadoof works out to

litres.		strokes.		min.		per hour.
20	×	7	×	60	=	8·4 m^3

but that is continuous work not possible for one man.

The shadoof is an excellent conception. The man gets the weight of his body pulling down, and can exercise far more force than he could in lifting-up work, which is done for him by the counterpoise. There is no complication of parts with resulting friction. The number of shadoofs in Egypt is enormous and their working absorbs a very great proportion of the labour force of the country.

The *Sakieh*.—When water is drawn from a well the ordinary means is a bucket and rope, but that is too slow when large quantities are required. In India the bucket becomes half a bullock's skin fetching up 200 litres at a time from a well of a depth of 20 metres. Two bullocks walking down an inclined plane are needed to raise this weight of water. An ingenious tripping rope upsets the bucket when it reaches the top, and the animals return unloaded up the slope whilst the bucket descends.

The sakieh has an endless rope, sometimes of straw, carrying earthen pots or buckets at intervals of 2 to 3 feet. This rope passes over a vertical wheel having on its axle

a rough wooden cog wheel, actuated by another wooden cog wheel, placed horizontally, to the axle of which a pole is fixed for attaching the bullock which gives the motive power. The sakieh is suitable for raising water to heights of 3 to 8 metres. The rope hangs free in the water and

FIG. 54.—THE SAKIEH.

as the wheel revolves the pots are filled in succession, carried up, and as they pass over the wheel are emptied into a receiving trough which carries off the water. According to height of lift and number and size of pots, one or two animals are required, and to still further adjust

the work to the power of the animal or animals the cog or the vertical wheel has 24 or 36 teeth. The sakieh is made by the village carpenter with the wheels and axles all of wood. It can be easily repaired.

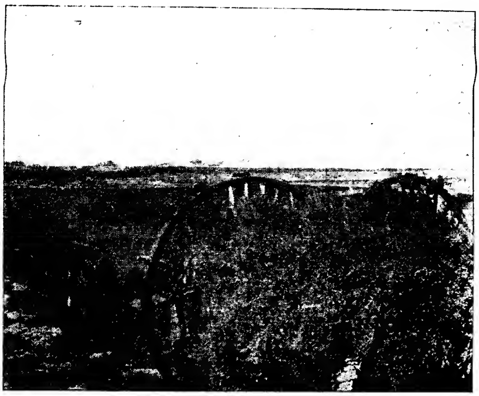

FIG. 55 *a*.—FAYOUM WATER-WHEELS.

In the Fayoum where canals have a much greater slope, and even a direct fall the current is used to turn a water-wheel, to the rim of which pots are fixed, and a certain amount of water lifted. Instead of pots fixed to it, the wheel frequently has a stiff hollow rim divided into compartments like the form of sakieh known as the taboot. For each 4·5 cubic metres available in a canal with a fall of 1 metre the quantity raised should be 1 cubic metre to a height of 4·5 m., but the friction and leakage cause so much loss of power and water that in practice not more than half this quantity of water would be raised.

The *Noria* is simply an European form of sakieh made of iron, with zinc buckets. A noria for 3 to 4 metres lift costs L.E. 20. If properly cared for and oiled it would last well. A sudden blow given to a bullock makes it jerk the machine, and might break a tooth from one of the cogs. When one or two teeth go others are soon stripped, and the whole apparatus rendered useless, and beyond the repair of the village carpenter.

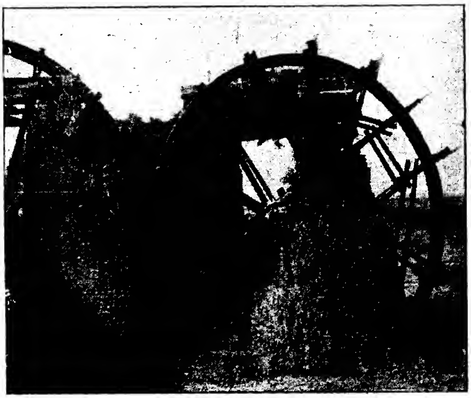

FIG. 55 b.—FAYOUM WATER-WHEELS.

The *Taboot* is a form of sakieh used in Lower Egypt for lifts of from 1 to 3 metres. Instead of the rope and buckets the wheel called "Tara" has a stiff hollow rim divided into compartments. As these dip into the water they fill, and when carried up to two-thirds of the diameter of the wheel they discharge their water into a side trough. Another form discharges its water at the centre of the

wheels the lift in this case being only half the diameter. This form is more like the elaborate "Tympan" with its volute formed compartments, which can only be made in thin iron plates.

As the tara carries water at its circumference its largest diameter rarely exceeds 5 metres for a lift of 3 metres. Larger wheels than that cannot be made stiff enough

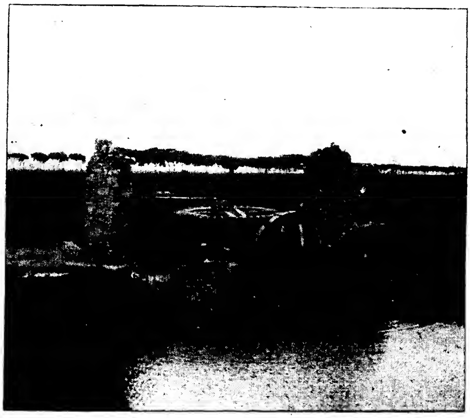

Fig. 56.—The Taboot.

without too greatly increasing weight and cost, and the load of water carried at the circumference acts against the motive power with a leverage in proportion to the radius of the wheel.

The tara is made of very thin wood, and in many small pieces, and it will not last over two seasons. If instead of making the divisions of the compartments at right angles to the plane of the wheel one makes them at an

angle of 45° the wheel carries the water to a greater height and discharges it more rapidly with less spilling.

The taboot is best for lifts of 1 to 2 metres. It is assumed to have a discharge of 30 cubic metres per hour, but it varies much according to lift. It costs from L.E. 5 for a small lift, if not built in masonry, to L.E. 20 and more for larger sizes placed in masonry wells. It suits the country well, its main faults being rough construction and frequent need for repair. The great rough cog wheels with large wooden teeth of 5-inch pitch are often ridiculed but the transmission of one bullock power at very slow speed requires theoretically wide-pitched teeth, and the practice of the village carpenter has sound scientific basis. He has a regular scale for altering the number of teeth according to the diameter of the wheel and consequently the work to be done.

Archimedean Screw.—This may be the small wooden barrel 2·5 m. long × 0·40 m. diameter which a man carries to the field on his shoulder and begins to work with the preliminary of driving a post into the water to receive the lower thrust end, and another post at a higher level to serve as the upper bearing. Such a screw costs P.T. 60, will lift water 0·75 metre, and is often used to supply a sakieh when water in a canal falls just below its reach. Sometimes two or three screws are used, one above the other. Worked vigorously by 2 boys they will do nearly as much as a sakieh. These small wooden screws have a double spiral in the centre.

An improved screw, "Tambour, Yanni," has been intro-

duced. It is an iron spiral working in an open masonry inclined trough. The spiral has a diameter of about 1 metre, and is worked by iron gearing turned by a bullock. On 0·75 to 1 metre lift this screw will water 1 feddan per hour, say 250 cubic metres, which is far beyond the capacity of any other bullock machine. It is strongly made and costs complete with masonry about L.E. 60.

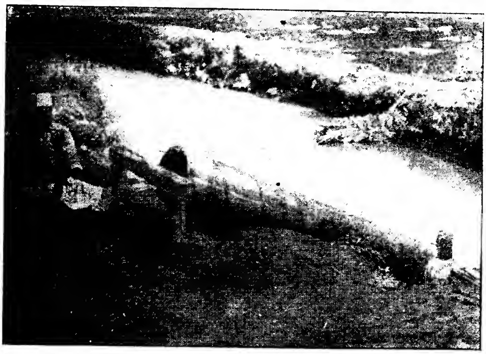

Fig. 57 a.—The Archimedean Screw.

Large archimedean screws driven by steam engines have also been in use in Egypt. Those at Khatatbeh pumping station were 4 metres in diameter and 12 metres long, with a capacity of 120 cubic metres per minute each. Faulty construction at this installation rather discredited screws of this large size in Egypt.

The benefit of a screw is that, turned fast or slow within reasonable limits, it will give out water in exact proportion to its speed. For this reason if attached to a windmill it would always lift some water, whereas a centrifugal pump

would cease to act when its speed was reduced below a certain point, and if run too fast would not turn out a correspondingly increased volume of water.

With an archimedean screw, the height of water on the down-stream side may vary without interfering with its work, but the discharge channel should maintain an uniform level. The limit of lift is about one third of the

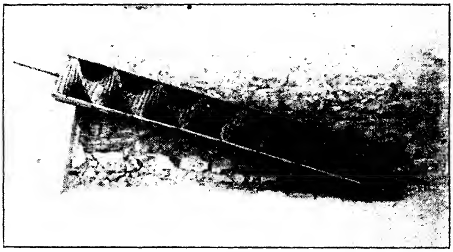

FIG. 57 *b*.—CONSTRUCTION OF THE ARCHIMEDIAN SCREW.

length, and length is limited by the heavy weight of water and tube which at Khatatbeh amounted to 70 tons and proved too much for safe working. The angle of the tube with the horizon is usually 33° and the angle of the spiral 45°, but variation of either of those angles involves altering the other.

Scoop Wheel.—Otherwise called Dutch wheel. Except at Atfeh on the Mahmoudieh Canal these wheels are not in use in Egypt. In Holland, where they originated and where they are often used in connection with windmills, they have been largely displaced by centrifugal pumps.

They are not suitable where either intake or outfall channels vary in level. If the float is submerged in the

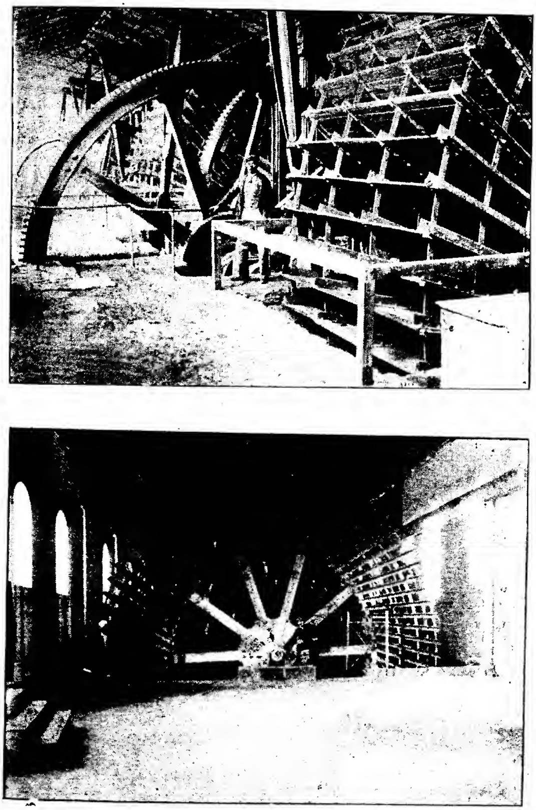

FIG. 58.—SCOOP WHEELS AT ATFEH.

intake channel it has to meet the resistance of the water to its whole surface and it drives before it more water than

it can lift. Unless the back is shrouded in, the excess falls back over the float and much work is lost. The same thing happens with too high an outfall channel.

The Atfeh scoops are 10 metres in diameter, 3·60 m. wide, make 1 ½ revolution per minute and can discharge 300 cubic metres per minute at 2·50 m. lift.

Scoop wheels need very heavy and expensive foundations and are not likely to be again erected in Egypt. Small ones on 1 to 1 ½ metre steady lift, driven by windmills, might possibly be adopted in the Delta along the coast.

Centrifugal Pumps.—These are the best all round

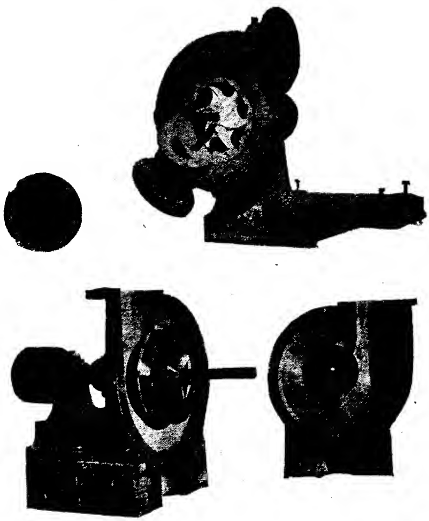

FIG. 59.—CENTRIFUGAL PUMPS.

machines and the only ones with any elasticity of lift when there is variation of intake or outfall levels.

Centrifugal pumps are measured by the diameter of the suction pipe. The discharge in cubic metres per minute on lifts of about ·3 metres is found approximately by the following rule: —

	(Diameter in feet²)	× 10 =	cubic metres per minute.		
Thus a 12-inch	1 × 1	× 10 =	10 cubic metres per minute.		
18 „	1·5 × 1·5	× 10 =	22·5	„	„
36 „	3 × 3	× 10 =	90	„	„
48 „	4 × 4	× 10 =	160	„	„

For easy calculation this rule gives fairly accurate results.

The speed of water in the suction pipe of a pump is usually $2\frac{1}{2}$ metres per second although higher speed is now often used. To attain this speed on a high lift the engine runs correspondingly fast, and it is found that if a large pump on a lift of 2·5 metres runs 70 revolutions per minute it increases to 90 revolutions when the lift is 3·50. Small pumps run faster than large ones as regards revolutions per minute but the speed of the tip of the fan is the same.

The commonest sizes of pump in Egypt are of 8 and 10 inches and often these are run by engines of 8 and 10 H.P. The engines are nearly always portable engines driving the pump by a belt. Engines are rarely ever moved, and so the expensive road wheels are only of service once in getting the engine to its destination. Small fixed engines, steadier in working and with parts more accessible, would suit better.

A 12-inch pump lifting 10 cubic metres per minute to a height of 2½ metres is only doing 5·5 W.H.P. A nominal 6-H.P. engine, which would indicate about double this power would work the pump, provided engine and pump were in good order. In Egypt an engine of at least double that power would be used because both pump and engine are not attended to. The pump fan wears till there is such a space between the fan and the casing that a great deal of water leaks past. It is not an expensive repair to put the fan to rights, and when it is done the pump will give 30 per cent more water for the same coal consumption. The boiler is also subject to neglect. The Nile water is muddy and a boiler should be blown down half a gauge glass daily to clear it of deposit, and every week it should be emptied and washed. Many boilers are allowed to silt up to the level of the fire bars and over that, and contain exceedingly muddy water. All this entails rapid deterioration of the boiler, waste of coal, and danger of explosion.

There is hardly a small pump in Egypt driven at proper speed. The water is lifted too high, and shoots out from the discharge pipe with far too much velocity. Such a pump is giving more water, but not in proportion to the extra power used and extra coal burned.

Coal consumption is the most important item in cost of pumping. For large pumps, makers will guarantee a coal consumption not exceeding 1 kilogram of good Welsh coal per W.H.P. per hour. As these installations are in the hands of competent European engineers pumps will run for very many years and exact coal consumption can

be calculated. Small pumps in bad order, with foul boilers, badly stoked, will use 8 or 10 times the amount of coal in proportion to the work done by large pumping engines.

Oil engines are coming into extensive use in Egypt. So long as petroleum keeps at a moderate price they are economical.

These oil engines are sized according to Brake Horse Power (B.H.P.), being the actual power given off at the shaft or by the fly-wheel. A 20-B.H.P. oil engine would have about the same power as a 10-H.P. portable or fixed engine. Oil consumption is from ·75 to 1 lb per B.H.P. per hour. A case of 2 tins of petroleum weighs 66 lbs., and would run a 20-B.H.P. engine from $3\frac{1}{2}$ to $4\frac{1}{2}$ hours. An engine of that size would run a 12-inch pump on a 4-metre lift, or when not pumping would work a corn mill with stones 1 metre diametre. Alcohol engines have also been introduced but are not yet in general use. A great deal of alcohol is manufactured at the sugar factories in Upper Egypt and, with a cheap local supply of this product, alcohol engines should be more generally used. In the Sudan, where petroleum is exceedingly dear, and where coal has not yet been found, alcohol might be manufactured in a cheap description of still, from any vegetable product containing starch or sugar.

Electric-driven pumps are little used in Egypt. A large Daira with numerous pumps, within a small radius, might generate power economically at one central station and distribute it by wire to the different pumps—or the power of certain Nile cataracts might be utilised for pumping. The possible cases in Egypt for the use of

electricity for pumping are few, and would require careful technical study of the local conditions before such power could be employed.

Gas suction engines are rapidly coming into favour. They are as easily worked by natives as the gas engines using petroleum. The consumption is 1 lb. of anthracite coal per B.H.P. per hour. Whilst the weight of coal used is much the same as petroleum, the cost of anthracite coal is only about one third the cost of petroleum.

CHAPTER VII.

LAND RECLAMATION.

ALTHOUGH Egypt has been cultivated for countless centuries, and one might even record its agricultural history in millenarian periods, there yet remains a large area to be reclaimed. The great salt lakes bordering the sea coast, Lakes Mareotis 70,000, Edku 60,000, Borollos 180,000 and Menzaleh 49,000 feddans with their marginal swamped lands, contain probably 1,000,000 feddans, whilst in almost every province in Egypt there is land which from difficulties of water supply or drainage, irregularity of surface, supineness or poverty of owners, has never been properly cultivated, or if cultivated in former ages has been allowed to revert. Remains of "basin" banks and of ruined towns indicate more extensive cultivation of the northern delta than actually exists to-day. The population has fluctuated greatly. Under the Pharaohs it was put at 7,000,000 and it increased much under the Ptolemies. The early Arab historians gave it as 12,000,000. In 1844 this had dwindled to 2,400,000 but thereafter it steadily increased until the census of June, 1897, which showed 9,734,405.* The increase is likely to continue. The country is extremely prosperous, plenty of work and plenty of food are at the command of all the rural population, marriages are readily entered into and children can be supported in comfort, whilst devastating epidemics are held in check. The loss of 40,000 by cholera in 1902 was only one half per centum—an almost imperceptible check for one year of the normal increase of 2·9 per cent per annum.

* The approximate figures for the census of 1907 are 11,192.000.

Boinet Bey, in his useful *Dictionnaire Géographique de l'Egypte*, says the cultivated area of Egypt is 5,650,000 feddans and the population 9,734,405 and that this represents 58 feddans per 100 inhabitants or 172 persons per 100 feddans cultivated. This dense and increasing population, which shows no tendency to emigrate to the thinly populated Sudan, confines its attention, in the absence of manufacturing industries, almost entirely to agricultural pursuits, and to support it more land must be put under cultivation. Reclamation of all waste land must go on, not only ultimately of the "Berea" in the north Delta but of all uncultivated portions of the more highly cultivated provinces. The marked increase of land values in Egypt during recent years, the prosperity of the people putting them in funds to buy and develop land, fixed land-tax not exceeded in its collection, equitable and more ample distribution of summer water, easier loans provided by the Agricultural Bank of Egypt, are all contributing factors leading to the extension of land reclamation. Moreover the fellahin and even the wealthier Egyptians know of no other investment for surplus money except land. The payment for the cotton crop yearly leads to the absorption into Egypt of a large amount of money, averaging L.E. 2,000,000 per annum, hoarded in some cases up to a certain amount, but destined ultimately for investment in land.

Reclamation will go on till Egypt reaches its final limits. This extension must cease with reclamation of the sea-board lakes and waste lands of the interior, in all probably not exceeding 1,500,000 feddans, an addition of say 24 per cent to the present cultivated area. The valley of the Nile is bounded on both sides by high and even mountainous

land incapable of cultivation under any circumstances. The Delta is also surrounded by desert and, even if cheap fuel and greatly improved pumping appliances enable irrigation water to be economically applied to land requiring high lifts, still the possible expansion into a high desert of unequal and varying level is very limited.

Reclamation of land necessitates the following operation:—first, irrigation; second, drainage; third, levelling; fourth, cropping; fifth, village building. The manner and extent of these various operations depends on the locality and nature of the land taken in hand.

In the "Berea" district drainage is the first necessity. Levelling is of minor importance as the beds of the lakes show almost no inequality though there may be a very gradual slope, so gradual that when the land is cut up into small sections these are practically level.

The small areas of waste land in villages have generally irrigation and drainage close at hand and levelling is the heavy item. They have been left uncultivated for this reason.

Border desert lands need little drainage, but irrigation necessitates extensive water lifting, and levelling is in many cases serious.

Nearly all the reclaimable land in Egypt consists of the great lakes and their margins, and the principles to be followed in reclamation will be best illustrated by a consideration of what has been done at Aboukir. Lake Aboukir, the smallest of all the lakes on the sea coast, begins six miles east of Alexandria and occupied an area of fifty square miles, or 29,621 feddans. It lay between the Mahmoudieh canal and the Bay of Aboukir. The dimensions were 12 ½ kilometres in length, east to west, and

$9\frac{1}{2}$ kilometres in width, north to south. The bed of the lake was nearly a dead level, one metre below sea, rising by a gentle slope to R.L. 0·50 on the west and east margins. Aboukir was not a permanent lake. Drainage from adjoining cultivated land on the east, and winter rainfall averaging 20 centimetres per annum caused an accumulation of water in the lower parts to a depth of 30 centimetres in winter, but this was evaporated during summer leaving a crust of white salt, nearly pure sodium chloride, a few centimetres thick. Clearly marked traces of old water channels and remains of foundations of houses confirm historical proof that Aboukir was cultivated, probably till the middle of the eighteenth century when an irruption of the sea destroyed the cultivation.

Voelcker's analyses of two samples of soil from the bed of the lake taken at different points give the following results:

ABOUKIR SALT SOIL.

	No. 1	No. 2
Oxide of iron	11·69	11·04
Iron pyrites	0·08	0·11
Alumina	6·36	10·88
Lime	2·08	7·73
Magnesia	1·79	0·93
Soda	0·79	—
Sodium chloride	8·11	8·56
Potash	0·65	1·23
Sulphuric acid	2·23	2·56
Carbonic acid	0·19	4·75
Phosphoric acid	0·16	0·19
Insoluble silicates and sand ...	62.23	45.81
* Organic matter	3·64	6·21
	100·00	100·00
* Containing nitrogen	0·035	0·070
=Ammonia	0·042	0·079

The work of reclamation began in April, 1887.

The first problem was how to drain the lake. This could be done in two ways, either by pumping, or by draining through syphons under the Mahmoudieh canal into Lake Mareotis, which in winter rises to R.L.—2·25 and in summer falls to R.L.—3·50, thus affording sufficient drainage. Unfortunately, the Egyptian Government at first refused to sanction syphons although these were afterwards sanctioned in 1891.

It was decided to instal pumps. The installation consisted of two of the well-known Hammersmith firm's—Messrs. J. & H. Gwynne—"Invincible" centrifugal pumps with suction pipes 48 inches in diameter, each driven by a horizontal direct-acting compound surface condensing engine with cylinders of 17 and 32 inches diameter and stroke of 27 inches. There were 4 Galloway boilers, 20 feet by 7 feet, providing plenty of reserve power. The pump volutes were 15 feet 6-inches and the fan 6 feet 9 inches in diameter. Circulating water was driven through the condensers by two 6-inch centrifugal pumps each driven by a direct-acting engine. The small circulating pumps were not necessary, as the outfall channel communicating with the sea was always full of water standing above the level of the condensers, so water could easily be run through these by gravitation. The small pump engines running at 300 revolutions per minute require packing and tightening up more often than the main engines running about 80 revolutions and any little attention of this kind involves stopping the main engines which otherwise run continuously for periods of twelve to fifteen

days. Condensing by gravitation water is therefore a great advantage. The pumping engines were each guaranteed to lift 171 cubic metres of water per minute, on a lift of 3·35 metres with a consumption of 2 kilogrammes of Welsh coal per hour per horse-power in water actually lifted.

They worked fully up to this guarantee, and when they were afterwards removed to Mex to pump Lake Mareotis they worked night and day throughout the six months' pumping season (the total stoppages during the month being about 12 hours) and averaged 10 per cent. more water than the estimate on a coal consumption 10 per cent. less than the estimate.

When working at Mex the cost of the pumps, on a 3·5-metres lift, averaged per month:—

Wages...	L.E.	96
Oil and stores	,,	30
Coal 360 tons at 112½ P.T. = ...	,,	405
	L.E.	531

During the month, the pumps discharged 15,000,000 cubic metres of water, making the cost per million L.E. 35·40. The pumps averaged 100 million cubic metres during the season, October to April.

In 1901 at Atf, the Government pumped 40 million cubic metres in 36 days on a lift of 1·83 metres using per million cubic metres 12 tons of coal costing L.E. 1·710 per ton. The cost per million was L.E. 52·70. At Mex where there are now, besides the two "Invincible" pumps, 5 Farcot pumps, the water pumped was 316 million cubic

metres on a mean lift of 3·02 metres using per million metres 19 tons of coal costing L.E. 1·746 per ton. At Atfeh the cost is increased by charging maintenance and staff though pumping only 36 days in the year.

There are many large pumping stations for the drainage of low lands and marshes in England, Holland, Italy, France and elsewhere and steam-driven centrifugal pumps have displaced scoop wheels and Archimedean screws driven either by steam engines or wind-mills. There has recently been installed in Upper Egypt a pumping station which, by the use of Green's Economiser and superheated steam, is said to have reduced coal consumption to 2½ lbs. per water horse-power per hour. In reclamation works dependent on pumping there is this difficulty, that at first the length of drain made does not afford reservoir capacity to allow intermittent action of the pumps. If the pumps evacuate water more quickly than the drains bring it to the sump, the latter is rapidly lowered and the pumps are working on a high lift and have to be stopped before land at a distance at say 10 miles begins to feel the effect. Then if the drains convey more water than the pumps can lift their level rises at the sump end. Centrifugal pumps to work economically must run at a certain speed, lifting a fixed quantity of water, and it is impossible to regulate drainage so that exactly this quantity is brought to the pumps and a fixed level maintained in the drains. In reclamation works of any size, where the quantity of drainage varies at different seasons of the year, there should be at least two if not three pumps, so that one or two or all three may be worked as required at full capacity. As reclamation proceeds, more drains are made, till their

aggregate gives reservoir capacity, and a steadier level is more easily maintained.

The difficulty of maintaining steady levels in the drains led to the removal of the Aboukir pumps to Mex on the border of Lake Mareotis. That lake is from 1·50 metres in winter to 2·50 metres in summer below the level of Aboukir lands, and drainage by gravitation is obtained by means of three syphons under the Mahmoudieh canal. Two of these syphons are malleable iron pipes $\frac{5}{16}$ inch thick, with a diameter or of 5 feet. They rest on a bed of concrete and are surrounded by a thin layer of concrete on sides and top. The third syphon is a two-arch one built of bricks in cement, each arch being slightly more in area than the 5-foot pipe. Even had the pumps remained they would not have been sufficient for the drainage of Aboukir and the adjoining lands—36,000 feddans. The average drainage for the year from cultivated land is usually accepted as eight to ten cubic metres per feddan per day and provision for 10 metres = 360,000 cubic metres daily from Aboukir drainage area, would be enough during the greater part of year. But the preparation of land for berseem requires heavy watering in September and October and ten cubic metres per feddan per day is very largely exceeded. Rainfall is a very serious consideration. The annual average is eight inches, varying from four to twelve inches, and the rain generally comes in storms of three days' duration. In January 1897, 2·6 inches fell in twenty-four hours, in December 1898, 3·5 inches in one week, in December 1902, 3·04 inches in 5 days. Before the third brick syphon was put in, the catchment area served by the Ramleh syphon

of the Aboukir land was 14,000 feddans. On this area the rain which fell from 25th to 29th December 1902 was 3·04 inches or 7·60 centimetres giving 324 cubic metres per feddan or 4,536,000 cubic metres for the total area. On 30th December the syphon was discharging with a head of ·97 metre, 437,833 cubic metres or 31·28 cubic metres per feddan. On 3rd January 1903 this had diminished to 304,261 cubic metres or 22·44 cubic metres per feddan, the head on the syphon being ·50 metres. From 4th to 6th January the rainfall was 1·54 inches (3·85 centimetres) and drainage on 5th was 332,486 cubic metres or 23·75 cubic metres per feddan. These figures are for rainfall only, as during the whole period in question the head sluice was completely closed and no irrigation water was used. There is not a year in which there is not a fall of 2 inches in two or three days, and if it occurs in October, when berseem is only two or three inches high, much damage is done. To give reasonable protection against inundation, the drainage allowance should be 50 cubic metres per feddan. This only applies to the coast, much of the rain does not go inland more than fifteen miles from the sea, and in any case higher and less salt lands do not suffer so much.

Aboukir lands have now a syphon capacity equal to at least four pipes of 5 feet diameter for 36,000 feddans, and this not for ordinary agricultural drainage but on account of the rainfall. Syphons are often made much too small. In low-lying land such a loss of head as one metre, and even 0·50 metre, is fatal to good drainage. The sectional area of syphons should be calculated so that they may do their normal work with a head of not more

than 0·10 metre, and if extra drainage is thrown on them their capacity doubles with a head of 0·40 metre. The loss of 0·30 metre extra head will not do much harm if maintained for a short period. If, however, a syphon is calculated for a head of 0·25 metre, to double its capacity the head must rise to 1 metre and land will be damaged if not swamped. It is false economy to curtail the size of a syphon. The excavation of trench, deviation of canal where necessary, concrete bed and masonry heads cost nearly as much for a small syphon as for a large one. An iron pipe 1·5 metre diameter weighs only 40 per cent more than one of 1 metre diameter but its sectional area is 2·25 times as great, and it would carry with a 0·20 metre head an amount of water which could only be forced through the smaller pipe with a head of 1 metre.

The amount of drainage water which has to be provided for depends on various points but it should not be less than 50 cubic metres per feddan per 24 hours where there is considerable rainfall. The main drain of a block of say 5,000 feddans should be as large in sectional area as the canal which supplies that block. If all the 5,000 feddans were under reclamation at one time, the drain would have to be much larger, for whilst a canal runs full a drain should only carry water to $\frac{1}{3}$ or $\frac{1}{2}$ its depth. On 5,000 feddans, part would be reclaimed and giving only 10 cubic metres per feddan of drainage, part would be under process of washing and giving 100 cubic metres, and part would probably be untouched.

Ordinary crop irrigation requires 25 to 30 cubic metres per feddan per 24 hours, and the drainage resulting from this is 8 to 10 cubic metres, but in reclamation much more

water is needed and the amount of water which filters through the soil depends on the depth of water over the land. From a small plot 150 m. × 50 m. surrounded by small drains, water of a depth of 10 centimetres may all sink into the soil in 24 hours, but later the rate of drainage would be slower as the water filtered slowly through the soil. Such a plot would generally take 3 or 4 days for the water to disappear in winter with no evaporation to help. In dense soils the water will sometimes stand ten or even fifteen days. Whenever water stands on the surface more than five days, additional drains should at once be made. Salt land under reclamation should filter through it at least 50 cubic metres of water per 24 hours.

Irrigation for reclaimed land differs only from that of cultivated land in the quantity of water required. In the chapter on "Irrigation and Drainage" sections of canals are given. As reclamation is carried out during high Nile and in the winter months when supply is abundant, these new canals can be kept full and will carry more water than is credited to them. After the first and second years use they become silted and clearances are thrown on the banks and inside berms till they are reduced to a size just sufficient for ordinary irrigation and this size is thereafter maintained. With minor water channels the fellah knows how to deal, not unnecessarily cleaning those which are too large nor neglecting those which tend to become too small.

It is assumed that an area of 5,000 feddans of salt land is to be reclaimed, that the block is 5 kilometres × 4 kilometres, and that irrigation and drainage have been provided for. The minor canalisation is now done as follows. A

main central canal and an east and west boundary main drain divide the property into east and west "kisms" each containing 2,500 feddans. The kisms are then divided by canals and drains into "hods" 2,000 m. × 1,000 m. of 500 feddans each. Hods are subdivided into "hoshays," 1,000 m. × 300 m., of 70 feddans each. The hoshays are further subdivided by a small irrigating channel down the centre of each and drains at right angles to it and 50 metres apart, into "gattas." The unit is then the gatta 150 × 50 m. surrounded on all sides by a small bank thrown up in excavating the drains and these gattas contain one and three quarter feddans each.

The following diagrams show the arrangement of canals and drains.

PLAN OF KISMS

Scale 1 : 100,000

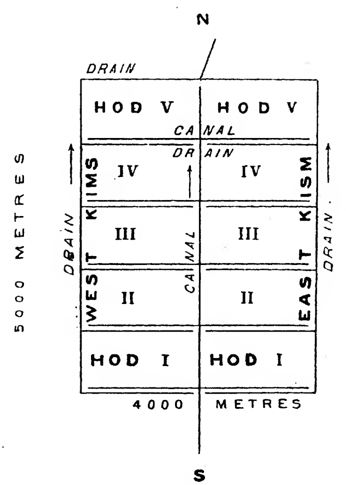

FIG. 60.—PLAN OF KISMS.

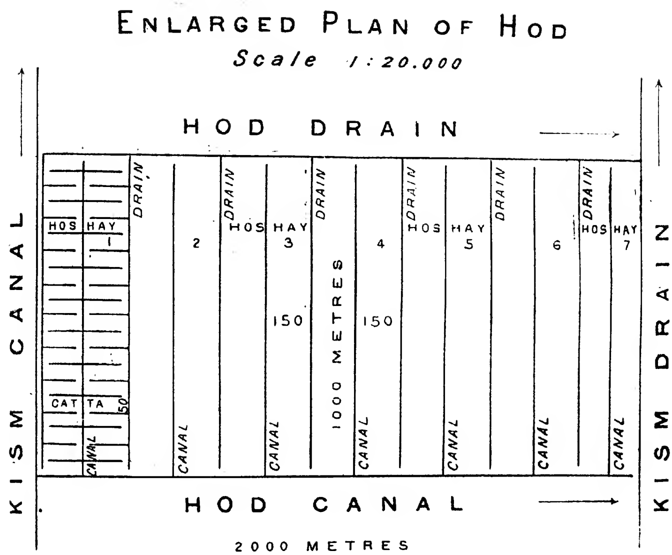

FIG. 61.—ENLARGED PLAN OF HOD.

The minor canalisation is generally done from April to July. The cost varies, but on a block of 5000 feddans it may be taken as follows:—

	Bed	Top.	Depth	Sec. Area	Length	Total	Rate per M^3	Cost	Total Cost	Per Feddan
	M.	M.	M.	M^3	M.	M^3	MIL.	L.E.	L.E.	L.E.
Kism work :										
Canal	2·00	4·50	1·25	4·0625	5,000	20,312	15	305		
Drains...	1·50	4·50	1·50	4·5000	14,000	63,000	15	945	1,250	0·250
Hod work :										
Canals...	1·00	2·50	1·00	1·75	20,000	35,000	12·5	437		
Drains...	1·00	2·50	1·25	2·1875	20,000	43,750	12·5	547	984	0·197
Hoshay work :										
Canals...	·50	1·50	·75	·75	70,000	52,500	10	525		
Drains...	·50	1·50	1·00	1·00	70,000	70,000	10	700	1,225	0·245
Gatta work :										
Drains...	·30	1·20	·80	·60	400,000	240,000	10	2,400	2,400	0·480
										1·172
Add for Head sluice, ridges, syphons, pipes etc.									1,641	0·328
TOTAL...									7,500	1·500

Rates of earthwork vary. On Aboukir they are 25 per cent under those stated but the salt soil there is always moist and easily worked with shovels. Elsewhere on dry harder soil, work has to be done with fass and basket and costs more. Hod canals should have small brick masonry heads, but fireclay or cement pipes 30 centimetres in diameter are sufficient for hoshay canals.

Washing.—The canalisation being completed the next step is to wash the land. This begins in August or September when the Nile flood is available. The gattas are filled with water to a depth of ten centimetres, and kept continuously supplied, and the water is allowed to filter through the soil dissolving out the salts. The filtration water which finds its way into the drain is exceedingly salt during the earlier stages of washing. As much as 15 per cent. of salt is sometimes found in the drain water, and even when the sweetening process has considerably advanced 2 to 3 per cent. is generally found.

If there is a white crust of salt over the surface of the ground it is very quickly taken up in solution and the water may then be run off into the drain and a fresh supply introduced. A four-inch crust of solid salt has been removed in a week by one washing. It is only at the very first that surface washing is permissible. Natives often keep a constant stream of water running into a plot at one end and off at the other. The effluent water is not perceptibly salt to the taste which means that there is less than one half per cent of salt in solution. Enormous quantities of water are wasted by this method, and

drains are kept at far too high a level. If drainage had to be pumped the cost of surface washing would be prohibitive.

When the level of water in a drain can be kept down 75 centimetres below the surface of the land, then by the filtration method a 75-centimetres layer of soil can be sweetened, the drains carry little water and that water holds much salt in solution, whilst little irrigation water has been used. If the same land were washed by the surface method, the drains would stand nearly full and not above 25 centimetres of the surface soil would be sweetened.

It is true that by merely passing large quantities of water over the surface of the land the soil will become sweet, even without any drains being made. There are examples of that wherever a canal or comparatively sweet drain flows over the marginal land of any of the lakes. Around all such escapes, reeds and coarse grasses spring up. The process however is exceedingly slow. The action which here comes into play is that of the diffusion of liquids. The salt water of the lower stratum gradually works to the sweeter water above, mingles with it and is carried off, and so salt is gradually eliminated. The salt water table not being permanently lowered and kept down by drains, as soon as the supply of fresh water ceases, capillarity quickly brings up salt and the lands revert. It is only where there is constant escape that reeds flourish. Where the escape ceases reeds do not grow and it is not for want of water, for some kinds will last a summer without irrigation. It is because the salt returns where there are no drains.

Colmatage for salt lands, unless in exceptional cases, is not to be recommended. If the 5000 feddans now under consideration were treated by colmatage there would be the kism and hod work to divide it into 500-feddan plots but the earthwork would have to be much heavier and large banks would be made as considerable waves can rise in 500-feddan areas. The cost would be at least 50 P.T. per feddan. Assuming abundant water, the time to sweeten the land would be much longer than by filtration washing. When the land did become sweet, the hoshay work would then have to be done to ensure keeping down the salt and also to divide the hods into suitable areas for irrigation and cultivation. If the colmatage was of any use, a great crop of reeds and weeds should be on the land requiring at least two extra ploughings. As for silt brought to the land, it can only be distributed by canals, and with one opening into a 500-feddan block there is no current to carry the silt any distance. Mere discoloration of water does not indicate much silt, and it will be found that away from inlet and outlet currents, the water is standing green and almost motionless.

Colmatage takes more time and more water, and in the end as much, if not more, expenditure than filtration washing. Where old heavy banks exist, and there are large silt-carrying canals with water which would otherwise be wasted into the lakes, colmatage may be carried out on lands which would otherwise lie waste. If continued many years the reeds give place to grass, coarse but fit for pasturage, and ultimately such lands will come into cultivation. As a method of reclamation, however, it cannot

compare with minute canalisation and washing. The State Domains experiments at Bechbiche (see Vol. V N° 3 of the Journal of the Khedivial Agricultural Society and the School of Agriculture) entirely confirm this opinion that colmatage is slow, costly and unsatisfactory.

There is a colmatage or warping being tried on the Nile foreshores and byewaters, south of Cairo, by a company, but that is an entirely different thing. It depends on checking the current which then fails to carry the silt, and that is deposited. Part of the sloping bank or foreshore is enclosed with a stone dyke; water is admitted freely and silt deposited. Or, one of the side branches is dammed at top and bottom, and a large quantity of water admitted by a regulator which when closed stops any current, and the silt at once falls to the bottom. The surface of the land will gradually be raised, more rapidly at first when the depth of water is great, and slower as the level of the land rises. In this kind of warping, the main Nile can be drawn on without limit so long as it maintains the height necessary to cover the land. It is a very different matter to attempt colmatage in the northern delta, with shallow intermittent floodings drawing water from a canal by means of a pipe.

The washing process on fully drained land continues from September till April, if water is available, and during that period the land is never dried. It might be better to fill up a plot, let the water filter through, and then the land would dry and crack. The next supply of water would penetrate quickly and deeply through the cracks. But on the seaboard there is a rainfall of eight inches, all

of it during the winter months. Before the land can dry, fresh rain falls and, besides, the salt in the soil holds so much moisture that land will not crack till it is comparatively sweet. Cracking with fissures an inch wide and eight inches deep is a sure sign of sweetening. Nile alluvium when quite sweet cracks in summer to a depth of several feet and the cracks are three or four inches wide. Some plots sweeten very slowly as the water will hardly filter through. It is useful then to shut the water off a hoshay, carefully note the gattas which retain water on their surface, and, in every case where the surface is not dry in five days an additional drain should be made up the centre of the gatta dividing it into two parts with a width of 25 metres each.

Sweetening takes place first on the surface and alongside the drains, and more slowly the greater the distance from the drains. The following are actual results of estimations of sodium chloride or common salt.

AMOUNT OF SODIUM CHLORIDE (COMMON SALT) IN LAND UNDER RECLAMATION.

Depth	Unreclaimed land	1st year	2nd year	3rd year	4th year.
15 cent.	8·17 %	1·17 %	·212 %	·29 %	·15 %
30 cent.	—	4·50 %	3·130 %		·26 %

Constant filtration of water through the soil infallibly removes salt but from the centre of a gatta to the side drain, a distance of 25 metres, there is a slope of the water table, and therefore it is some years before the subsoil in the centre at a depth of 50 centimetres becomes sweet. Diffusion of liquids must however help to sweeten even to depths below the level of water in the drains.

Levelling.—When the gattas are flooded with water it is at once apparent that the land is not absolutely level. This has to be remedied. If any land shows above the water it will not sweeten, for it is only by getting the water above the soil and allowing it to filter through that the salt can be removed. Canal banks of fifteen years' standing are, in the centre, as salt as when originally made. Cultivation also demands perfect levelling. If a gatta is ten centimetres lower in one part than in another young rice would be swamped out and so would young berseem. The greatest difference of level in a field of either of those two crops must not exceed five centimetres. As levelling must be done, the sooner it is taken in hand the better, for high land does not wash. When ultimately it is levelled down to the lower parts, such soil, being lightly deposited, washes very quickly but the part which has been laid bare exposes crude unaerated soil and crops on that will be inferior for several seasons. In one case, where a metre depth of old cultivated soil was removed to fill up a hollow, the crops on the bared land were inferior for five years. This had nothing to do with salt but was purely a question of crude unaerated soil.

If the inequality of surface does not exceed ten centimetres the levelling is done with the lowatah, (Fig. 30) a board four metres long by thirty centimetres deep with a strip of iron along its lower edge, and held upright by a handle. It is dragged over the flooded surface and the board pushes the accumulated earth or mud before it till a depression is reached, where the load can be gradually distributed by slightly raising the board. When the

inequality is greater than ten centimetres the levelling is done by the kassabia or bullock-scoop, similar to the American road scraper but without wheels (Fig. 29). The high land is ploughed and then the scoop comes, drawn by two bullocks. It is dragged through the ploughed land to fill it and it is this filling which is the heaviest strain on the bullocks. The scoop when full is drawn to the place where soil is required and upset to empty its load. Levelling is exceedingly laborious and costly work. A minimum slight lowatting to rectify quite insignificant inequalities will take five days' work per feddan of a pair of bullocks.

In levelling with the scoop, a good deal of labour may be saved if the land to be levelled is divided into plots of moderate size. The following diagrams illustrate this.

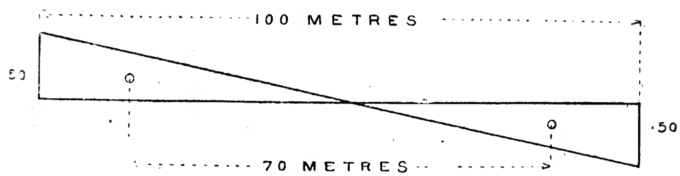

FIG. 62.—DIAGRAM.

To level this plot, 525 cubic metres per feddan are moved an average distance of 70 metres.

If the same plot is divided into two by a drain and made into two plots, one 50 centimetres higher than the other, the work is greatly reduced, being only one fourth of the above.

The work is now 262 cubic metres per feddan moved 35 metres or half the quantity to half the distance (Fig. 63).

There is an objection to having land at different levels, as the higher land causes infiltration to the low but this

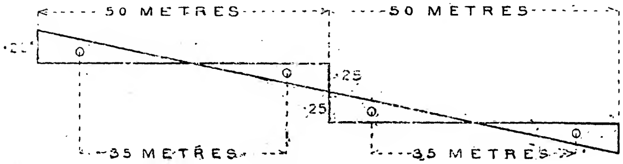

FIG. 63.—DIAGRAM.

can be obviated by a drain separating the two, provided always that the drain is kept in good order.

The scoop when full holds one fifth of a metre cube. The amount of daily work which can be done by a pair of bullocks is approximately as follows:—

Lead.	Cubic metres.	Number of Scoops.
25 m.	30	150
50 m.	17	85
100 m.	10	50
200 m.	5	25

Allowing 25 metres on each journey above the length of lead for filling and emptying the scoops, the bullocks must travel twelve kilometres per day. One has only to watch the frequent long stops and very slow speed of bullocks at kassabia work to be satisfied that the foregoing estimate of work is high.

A not uncommon instance of levelling would be taking down a gradual slope of 30 centimetres to a distance of 200 metres. That involves the transport of 415 cubic metres per feddan to an average distance of 140 metres and yet such land would appear level to the eye. Bullocks

would not make more than forty trips per day transporting eight cubic metres. This is 52 days work per feddan costing 12 P.T. per day for bullocks and man or over L.E. 6 per feddan to remedy a slight slope.

When land is really uneven and a metre or more is removed to fill adjacent hollows, the cost often runs to L.E. 20 per feddan. A heavy iron lowatah worked by steam ploughing engines is now in use by several large administrations in Egypt. Half a dozen ordinary kassabias have also been attached to a beam and worked by steam ploughing engines. The speed is much greater than is attained by bullocks. Two engines are needed, and if levelling down is all in one direction one engine only pulls back empties. Another form of kassabia is a large iron box carried on rollers. This requires heavy engine power, but is very effective especially on sandy sand.

Cultivation.—There is no crop which will grow on land containing two per cent. of common salt and there can be no proper cultivation on land with one per cent. It is easy to wash salt out of land till only one or two per cent. remains, but this residual salt is quite enough to prevent crops growing. When land has been washed as described, for six months, it is then ploughed and sown to dineba, a small millet, botanically "Panicum Crux Galli" or to rice. Dineba is a waste product of the rice mills and is cheap. It will stand more salt than rice and will not die so readily as that crop if water is scarce or even lacking for some days. Rice seed often contains much dineba and it is quite common to find fields where rice has all died down

from salt or insufficient irrigation and yet the dineba has remained vigorous. It is an excellent green forage in summer and autumn, and might be made into hay or silage. Dineba may be sown from April till August. On doubtful land it is by far the best crop to try.

Rice needs abundant water and careful handling in its earlier stages and on reclaiming land very often fails. Sultani rice, sown in April or May, occupies the land for six months. Sabaine rice, sown in August, can be carried on by the Nile flood when water is abundant, and with it there is not the same risk as with sultani rice.

Samar, a reed used for making mats and rush-bottomed chairs, is a hardy reclaiming crop cultivated largely in the Wady Tumilat.

Any of these crops show how the land is sweetening and dineba is specially useful for the purpose. It may be sown thinly merely to test the sweetness, and the result of such field experiments has been exactly confirmed by chemical tests in the laboratory. Where dineba grew well the soil was sweet, and the goodness, mediocrity or badness of different patches exactly conformed to the percentage of salt found.

Certain crops, such as rice, are credited with "consuming salt." This is pure fallacy. Rice grain and straw does not contain one per cent. of ash, and of the ash about one quarter only is potash and soda. No possible rice crop could remove ten kilograms of salt from a feddan.

When dineba or rice have been grown successfully, they are followed by a winter crop of berseem, i.e. Egyptian clover, but if dineba has not grown it is useless to

attempt berseem and the land is therefore washed a second year. The great goal in reclamation is to grow good berseem, for when that is attained, all other crops follow. By the third year cotton can be grown, but the land has not then reached full development for it continues to improve for some years. There are always spots which remain backward even to the fifth and sixth year. Extra drains, ploughing and washing are the best means to bring them on. Unreclaimed land is generally poor in organic matter and in nitrogen, and for this reason, berseem growing is strongly recommended. Ploughing before the first season's washing is useless on salt land. It is better to reserve it till the land has been sweetened to some inches in depth.

It is necessary to have houses for the men in charge of washing the land. One man can look after a hoshay of seventy feddans. A few houses are therefore built the first year. Later, when ploughing begins and more men are employed, the number of houses is increased and cattle sheds and magazines are built and ultimately full accommodation is provided for tenants.

If land is let to tenants, they should not, on any account, have it given to them until it is in good order. To do so is a most fatal mistake. Given good land the fellah will work it well and pay his rent, but with semi-reclaimed land belonging to another, he will not exert himself, and at the end of his lease the land will be returned with arrears of rent due, drains in bad order and the land no better than when he got it.

CHAPTER VIII.

MANURES.

With the possible exception of the quantity of water available for irrigation purposes, probably no question receives more attention at the hands of agriculturists than that of manures and manuring.

Though Egyptian soils are undoubtedly, generally speaking, in a high state of fertility, yet the ideas which were at one time prevalent as to their inexhaustibility have, under the modified system of agriculture now in practice, been dispelled. In fact even the casual observer cannot fail to be struck with the importance which even the small cultivator attaches to his manure supply. It is only second in importance to his supply of water. It is in one respect of greater moment to him, for whereas the Government has, by the vast improvements which have been made in the irrigation system of the country, shown itself alive to his needs from this point of view, yet the manure supply has been a diminishing rather than an increasing one.

A brief glance at present day conditions, in comparison with those existing in the early part of the last century, will suffice to show that altered circumstances have of necessity brought the question into greater prominence. As long as Lower Egypt was under a system of basin irrigation, and receiving consequently the life-giving deposit of the Nile annually, the soil received as it were sufficient manure to enable successful crops, under a suitable rotation, to be raised.

With the introduction of perennial irrigation, and hence a more intensive system of cultivation, the subject assumed an entirely different aspect, and it was soon experienced that the idea of the soils of the Nile valley being so rich as to require no manure was an erroneous one. As the cultivation of summer crops extended, especially of cotton, so the demand both for manure and water became an ever increasing one, and at the present time, when practically one half of the land of the Delta is under this crop, the natural resources of the cultivator as regards manure are overtaxed to supply a sufficient quantity for this and other crops. In fact the quantity of water and manure at the cultivator's disposal must govern the area which can be successfully put under summer crops. The two questions of manure and water are very intimately related, and in any irrigated country, their interdependence is a fact that is continually brought out. The supply of the one should always be considered in its relations to the supply of the other, and any increase in the quantity of water available for irrigation purposes without a corresponding increase in the manure supply is often of doubtful benefit. For example :— Sir Edward Buck referring to land near Ajmere (India) states as follows :— "Irrigation from tanks is lavish, and is put on to land which it has robbed of its fertility, as the manure supply, before deficient, is now totally insufficient to restore fertility. Given unlimited manure, water will raise the rental of land to *Rs. 50 an acre. With no manure it will sink to *R. 1 an acre."

* 1 Rupee = about 6¼ P.T.

This fact is again demonstrated in a very clear manner by Dr. Voelcker in his "Report on Indian Agriculture" as follows:—"In parts where rainfall is sufficient, manure alone may have to be sought, and where there is freshly reclaimed or virgin soil, or land enriched by silt, the supply of water alone may suffice; but these conditions seldom prevail. In the course of my enquiries I found that in every part where rainfall was light, water and manure were mentioned together, and it may be said without fear of contradiction, that one is necessary to the other, and that without the presence of both, the full benefit of neither will be obtained." This is well set forth in the following extract from the "Report of the Director of Land Records and Agriculture, Bombay Presidency 1888-1891":—"It cannot be doubted that (1) character and distribution of rainfall, (2) want of capital, and (3) want of manure, are the most important factors which regulate the demand for canal irrigation. As regards manure, the difficulty is great. Irrigated crops trench on the temporary fertility of the soil, which must be restored either by manure or rest. Irrigation, therefore, cannot be carried beyond the limits where the supply of available manure is fixed."

In Upper Egypt, where in the most favoured basins, a good deposit of silt has been obtained, and where no irrigation water is applied, the question of manure does not arise, but immediately artificial irrigation is resorted to the need for fertilizers at once arises. Even in the rich basin lands, where summer crops are grown by means of water from wells after the removal of the ordinary winter

crop, heavy manuring is practised. In the more southern basins where the soils are poor, the winter crops are largely grown by means of artificial irrigation and the manure which the latter always necessitates. In Lower Egypt, the question of the quantity of manure available is especially considered in its relation to the cotton and maize crops : while in Upper Egypt in addition to these, both sugar-cane and millet have to be considered, and in some districts cereals also. Maize has always been heavily manured, though it is only recently that the importance of cotton manuring has been fully realized. A detailed treatment of the various systems of manuring in practice will be found in subsequent chapters when dealing with the cultivation of individual crops. In the present it is proposed to deal with the various manures in use from a general point of view only.

When we consider the intensive system of cultivation practised in Egypt, and also that the whole of the soils are arable, we at once see that the demand for manure, under ordinary circumstances, must be very great. The fact that the system of irrigation is so perfect that a supply of water is always at the disposal of the farmer renders this even more prominent. For the ordinary purposes of successful agriculture, the Egyptian cultivator has therefore always the difficulty of procuring sufficient natural manure of a suitable nature to contend with ; and it is a fuller appreciation of this fact which has, during recent years, brought the subject into greater prominence.

Before entering into a consideration of the various manures in common use in the country, it may be

advisable as a preliminary to briefly sketch the nature of the part they play in the plant's economy. It is well known that plants remove from the soil in a soluble state certain substances which are necessary for their growth, and that the substances so drawn upon, exist in relatively small proportions. Though the total amount of any ingredient present may be comparatively great, yet it must be remembered that it is only that portion of it which can be brought into solution which is at present capable of feeding the plant, and which is in consequence known as the "available part." The remainder forms a reserve a part of which, by means of various agencies, may eventually be brought into that state of solubility which is requisite before it can nourish the plant. If land, therefore, be continually cropped and no efforts taken to restore, in some manner, the ingredients removed, it follows that it will eventually become exhausted; it will lose its productiveness. In a state of nature this does not occur, a condition which we have to imitate as far as possible.

The soil may be looked upon as the farmer's warehouse, from which he continually removes material in the form of crops. If this be continued without making any return, it follows that in the end it will be depleted. So, if we continually crop our land without making ample return for what we remove, we shall as it were diminish our store, and arrive at a point when the land will cease to give profitable returns. The richer the soil, the longer we may continue to draw upon it, but eventually the result will be the same. We can, however, prevent such exhaustion from taking place by giving the land an occasional rest, by

proper cultivation, by a suitable rotation of crops, and by the use of suitable manures. It is the latter with which we are chiefly concerned in this chapter.

The chief object then of manuring is to restore fertility to soils which are becoming, or have become, more or less exhausted, to enrich soils which are from their very nature poor, or to prevent exhaustion taking place, by returning to the soil in a useful form those valuable substances which are continually being removed by the crops we grow.

The word "fertility" is so often employed in connection with manuring that it is necessary to clearly understand what is meant by it, and what the essential conditions of fertility in a soil are. The reply which would generally be hazarded to such a question is that a fertile soil is one that contains a plentiful supply of plant food. This answer would however be incomplete, for there are many conditions that have to be fulfilled before a state of fertility is attained. We may say that fertility depends on the properties of the soil as classified under these three heads :—

I. *Physical.*
II. *Chemical.*
III. *Bacteriological.*

A discussion in detail of the physical conditions which influence the productiveness of a soil would involve technical details which it is desired to avoid, though, for a complete understanding of the action of manures a brief summary of them is necessary. One of the most import-

ant of them is the power of the soil to absorb and retain water.

In a country provided with a good system of irrigation this assumes less importance than in less favoured countries, where crops are entirely dependent upon rainfall. The more vegetable matter a soil contains, the greater is the quantity of water it can absorb: while, again, a clay will naturally possess greater power in this respect than a sandy soil. Soils of the latter nature, which would be very unproductive in a country dependent upon rainfall, are much more fertile in an irrigated country, though they require heavier applications of water. The power of absorption of a soil to a certain extent depends on the fineness of its particles, the amount of water which a soil can hold up being in inverse ratio to the size of its pores. Up to a certain point, the more finely a soil is pulverised, the greater the amount of water absorbed.

Closely related to the power of absorption is the power of retention. If long periods have to elapse between waterings, it follows that, other things being equal, the more water the soil can store up the more fertile it will be. The two properties of absorption and retention go, practically speaking, hand in hand: that is to say, the more water a soil can absorb, the more it can retain. Soils may possess these properties to even an injurious extent. There are for example some very dense clays in Egypt, which do not get rid of the excess of water applied sufficiently readily. They thus become sour and cold, conditions detrimental to the production of good crops. This fact is unfortunately not sufficiently recognised, and

it is by no means uncommon to see fields of cotton and sugar-cane flooded to such an extent that the surplus water cannot find an escape but remains stagnant for some time.

In some cases therefore, it may be our object to diminish retentive power; in others to increase it. As organic matter is most potent in this respect, it follows that the growth of lupins as green manure, practised on many sandy soils in Egypt, is an excellent plan, while the growth of berseem, in addition to improving the soil from the point of view of its nitrogen, also exercises a very beneficial influence on many soils in this indirect manner.

Green manuring is practised very extensively in Egypt. Crops are not grown except in the case of lupins with this as the primary object, but the ploughing in of berseem before cotton, which is so common, is a system of green manuring which is attended with most excellent results. At the time it is ploughed in there is a considerable amount of stem and young leaves on the plant, though the amount of organic matter thus added to the soil is not so great as when mustard, buckwheat, lupins, and other crops are grown primarily for this purpose in Europe. The frequency with which it is practised in Egypt, however, compensates for this, and it is impossible to over-estimate the importance of the effect which it has had on Egyptian soils. In the first place the mechanical condition of the soils has been improved, and when vegetable matter is thus incorporated in our heavy clay soils it opens them up, making them more light and

porous. For the improvement of light sandy soils, no better system is known than that of growing berseem, which not only greatly enriches them in nitrogen in which they are generally deficient, but also by the addition of vegetable matter renders them more absorptive and retentive and greatly enhances their value. In Egypt there is a great want of organic matter, and were it not for the system of indirect green manuring practised by the ploughing in of berseem, it is difficult to see how the fertility of our soils could have been maintained.

Some soils give up their water to plants much more readily than others. In a clay soil, for example, holding a considerable amount of water, plants cannot draw upon it to such an extent as when growing on land whose retentive power is less. Plants may wilt in clay containing 6 or 8 per cent. of water, whereas they will grow in a less retentive soil although the percentage of water be less.

Closely connected with the absorption and retention of water is the question of temperature. Though the temperature of the surrounding atmosphere largely influences the growth of the plant, yet it is affected to a very considerable extent by the temperature of the soil, and the warmer the land is, generally speaking, the more rapid will be the development of the plant. Soils of a sandy nature which hold but little water attain the highest temperature, and plants therefore mature more quickly on them than on those of a more retentive nature.

Another point to which reference may be made is the power of the soil to absorb gases. The presence of air

(oxygen) in the soil is necessary for the growth of crops, and especially so during the earlier stages. Not only is air necessary for the plants themselves but also for the numerous chemical and bacteriological changes which are continually taking place. In fact one of the evil effects of stagnant water in the soil arises from the exclusion of air, which results in changes injurious to the health of the plant. Thus, we may conclude that while manuring and fertility are closely connected, yet the latter depends on conditions other than the presence of an abundant supply of plant food. In fact it is quite possible to conceive a soil amply provided with all the necessary ingredients for plant life in a suitable form, and yet to be quite unproductive. It is clear therefore, that what is generally called the physical properties of the soil have a most important bearing on fertility, and that the presence of plant food alone should not be our only consideration. This is a point on which it is well to dwell, for many cultivators in attaching, and rightly, so much importance to the question of manure supply have shown a tendency to err in the direction of supposing that large applications of manures are all that are necessary for the raising of maximum crops. This is not only erroneous, but we may, on the other hand, state that the expenditure of large sums for manure, necessitates a more careful observance of the rules of successful husbandry in order that the fullest advantage may be obtained from the investment. There are many features to which attention could with advantage be drawn, such as the importance of the production of a suitable tilth, but these matters will receive

attention as occasion demands. Good drainage has been incidentally referred to, and from the practical standpoint has been fully treated in a previous chapter.

Presuming, however, that the soil from a physical point of view leaves nothing to be desired, the next condition of fertility and the one with which we are here more intimately concerned is the presence of sufficient plant food. Not only must there be a sufficiency but it must be present in such a condition that the plant is able to make use of it. The soil is a most complex body, and contains a great variety of substances. The bulk of it merely forms the medium in which the plant grows, provides mechanical support, and maintains those physical conditions necessary for its existence.

The part which is destined to feed the plant is relatively small in amount, while that part which is actually capable of feeding the plant at present is still more minute.

While a considerable number of ingredients are actually necessary for the growth of the plant, yet three of them assume greater importance than the others, viz:—nitrogen, phosphoric acid, and potash. These acquire importance from the fact that they are generally present in a form in which they can be made use of by the plant in smaller quantities than are the other necessary ingredients. An essential duty of the cultivator is therefore to ascertain whether his soil contains these ingredients in sufficient quantities, for the partial absence of one of them prevents the full development of the crop even though the rest of the necessary substances are present in an ample degree.

As a general rule, it may be said that we have only to occupy ourselves with these three all-important substances (with the possible exception of lime), and it is to supply any deficiency in them which may exist that manures are employed.

To determine whether such deficiency does exist, chemical analyses are often resorted to, though from one point of view these are of little direct value as evidences of fertility.

As has already been mentioned, it is only that portion which is soluble that can be taken up by the roots of plants; but what an ordinary chemical analysis indicates is the total amount present. It indicates potential rather than actual fertility. To overcome this difficulty, attempts are now made to estimate the amount actually available for the plant's use, that is the "available" part, which is continually being augmented by the breaking down of the insoluble or "dormant" ingredients by the numerous complicated processes which are ever taking place in the soil.

The soil water which acts as the natural solvent is charged with weak acids in solution, while again, the rcotlets of the plant themselves have a certain dissolving power, so that any solvent used in chemical determinations must be acid in its nature. Approximate estimates, it is considered, are obtained by the employment of a 1% solution of citric acid, this being the nearest approach to natural soil conditions obtainable.

By comparing the results of such determinations with actual field experiments, a similarity is observable which

has been accepted as evidence of the satisfactory nature of the solvent employed.

Manures then may be described as substances which when applied to the soil increase its fertility or productive power, and the three ingredients, nitrogen, phosphoric acid, and potash, are those upon which the value of a manure chiefly depends. They differ so much in their nature and in their action that it is almost impossible to consider them as a whole, while again, fertility, as accepted in the broad sense of the term, is dependent upon so many conditions, that some manures influence it in one respect, and others largely in an entirely different manner. In other words, fertility may be promoted in a variety of ways, and according to the functions performed by manures we may divide them into two main classes: (1) those which supply the soil directly with plant food. (2) those which exercise an indirect action.

The first class may again be sub-divided into: (*a*) those which may be called "general" in their nature: they supply the soil with practically all the ingredients necessary to plant life, and as they are usually bulky, exercise a considerable effect indirectly on the soil, (*b*) those which supply the soil with some particular ingredient: they furnish the plant with some ingredient or ingredients in which the soil is lacking, though to a minor extent, they may also exercise an indirect action.

The second class, consisting of those substances which mainly exercise an indirect influence, is of less importance. Lime may be taken as an example. Though it is possible that this substance may, in a soil actually deficient in it,

supply the plant with lime as food, yet its action is chiefly indirect. Another example of an indirect action of a manure may be cited in the case of gypsum, which is often employed in the reclamation of lands containing sodium carbonate.

Considering them, however, in order, we may take Nile mud and farm-yard manure as types of manures in this country which exercise both a direct and an indirect action. Green manuring has already been referred to.

Nile Mud.

In a broad sense, this may be looked upon as the manurial substance which has contributed more towards the fertility of Egyptian soils than any other. It in fact constitutes the soils of Egypt, which, unless impregnated with injurious salts, are almost invariably fertile. As is well known the red muddy water of the Nile deposits, during its sojourn in the basins, a valuable layer of rich mud. The soil is thus enriched annually, and, as already mentioned, as long as this system was practised in Lower Egypt there was not that need for manure which has arisen to-day. Warping, as sometimes practised to-day during the flood season for the reclamation of certain lands in the Delta, leaves a valuable deposit of mud and this in addition to removing a large quantity of salt for which purpose it is often primarily employed. The effect which this mud produces on the physical conditions of such lands is also one which must not be lost sight of, though it is with its value from a strictly manurial point of view that we are immediately concerned.

It may at once be mentioned that no extensive and systematic series of analyses have been made to determine its exact composition. Constituting as it does the soil of Egypt we should expect it to be, broadly speaking, of the general nature of Egyptian soils, though naturally, as the result of cropping, the latter must have undergone certain changes. Analyses of soils, however, especially those of Upper Egypt, should give results which are consistent to a high degree with those of Nile mud. The nature of the suspended matter in Nile water depends to a certain extent on the flood. In a year of high Nile, the matter in suspension, though great, is relatively speaking poorer than in a year of low Nile, the velocity of the water enabling sandy material to be carried along which would not be possible with a smaller volume of water of less velocity. During a medium year therefore, when the water is laden with more finely divided silt, the material is relatively speaking rich, while in years of extremely high flood it is poor. This, however, is in the latter case more than compensated for by the greater amount deposited. Analyses which have been made show great variations, chiefly, we think, owing to the time and manner in which samples have been taken. During its 50—60 days' sojourn in the basins, the water deposits the greater part of its mud. It may be assumed that upon entering, the red water contains from 150 to 200 parts of solid matter in suspension per 100,000, while the water of discharge contains similarly about 40 parts. If we take 170 parts per 100,000 as an average of the former, we have a total of 130 parts per 100,000 of water actually

deposited on the land. Owing to various circumstances, as for example, the position of the basin itself, whether at the beginning or end of a section, the position of the land in the basin, the nature of the flood, the figures given can only be regarded as an approximation, but at the same time they are sufficiently accurate for ordinary purposes. Again it is difficult to estimate the quantity of water which, on an average, enters the various basins, as, owing to the fact that it is continually passing through them even though they are full, the actual capacity of a basin does not accurately represent the quantity of water which has had the opportunity of depositing its mud.

As a general rule, we may state that the basins receive about 5,000 cubic metres of water per feddan, and on the assumption that 130 parts per 100.000 are deposited, each feddan receives about 6½ tons of sediment. The weight of an ordinary clay soil to a depth of 22 or 23 centimetres is from 3,000,000 to 3,500,000 rott per feddan, thus 6½ tons are equivalent to a little over 1 millimetre in depth. It would thus require 10 years to add a depth of 1 centimetre to the soil. As regards the composition of the deposit, as already mentioned, great differences are observable in the analyses at our disposal. The most reliable are probably those which have been made at the School of Agriculture, Ghizeh, and in which the composition of the suspended matter during flood is stated to be as follows:—

Insoluble matter and silica ...	57·54	per cent.
Potash	·53	..
Soda	·57	..

Lime...	3·07	per cent.
Magnesia	2·68	"
Oxide of manganese	·25	"
Iron oxide and alumina... ...	25·56	"
Phosphoric acid	·25	"
Carbonic acid	·73	"
Organic matter, etc.	8·82	"
(* containing nitrogen) ...	·14	"

These figures are quite consistent with the general composition of Egyptian soils. If on the other hand, Nile mud contained as high a percentage of phosphoric acid as that given by Letheby and Wanklyn (1·78 per cent), we should expect our soils to be phenomenally rich in that ingredient, and while they are not poor, and contain as a rule from ·2 to ·3 per cent, yet they are by no means as extremely rich as would be expected were Nile sediment so high in its content of phosphoric acid as that indicated in the analysis referred to. Again, the amount of organic matter given by Letheby and Wanklyn (15 per cent.) is considerably higher than has been found to be the case in the sediment at the time of flood, though it exceeds this at the time of low Nile. The potash given by these authorities (1·82 per cent.) is also extremely high.

Assuming the analysis already reproduced to be approximately representative, the addition of 6½ tons of mud per acre containing ·68 per cent of potash, ·21 per cent of phosphoric acid, and ·12 per cent of nitrogen would add to the soils in the basins annually :—

Potash	99	lbs.
Phosphoric acid	30½	"
Nitrogen	17½	"

To attach a money value to the above ingredients would be a very difficult matter, and in any case the actual manurial value would not represent the total benefit derived by the application of these amounts of valuable ingredients to the soil by means of an inundation. As already mentioned, the mechanical effect on certain soils and the fact that injurious salts are washed down beyond the reach of plants, attaches a value to warping on certain soils which may be in excess of the manurial gain. It must not be lost sight of, however, that very considerable quantities of soluble nitrogen must be lost to the soil by leaching. If we value the ingredients above at their present prices in ordinary commercial manures in Egypt viz:—potash and phosphoric acid at 2d. (8ms.) per lb., and nitrogen at 7d. (28ms.) per lb., we have the following result:—

		£. s. d.		P.T.
99 lbs. potash at 2d. per lb.	=	16 6	=	80½
30½ .. phos. ac. at 2d. per lb.	=	5 1	=	24½
17½ ., nitrogen .. 7d. ..	=	10 2½	=	49½
	=	£ 1 11 9½	or	154½ P.T.

Consequently, at soluble commercial fertilizer rates, the value of the mud deposited on a feddan is approximately equal to P.T. 150. We have now, however, to take into consideration, not only the fact that the various basins do not receive an equal amount of silt for the reasons already given, but also that its manurial ingredients are not in those available forms in which they exist in the manures with which we have compared it viz:—sulphate of potash, superphosphate and nitrate of soda, while on the other hand to estimate the real value of such a system of

warping we have to make an allowance for other benefits derived, and which have been already touched upon.

From the circumstances of the case it is clear that the sediment is in a very fine state of division, and from actual practical experience it is evident that the nitrogen becomes available for the plant, under the climatic conditions prevailing, at a greater rate than would perhaps be thought. We think, for the purposes of an approximate estimate of its manurial value, we may consider the nitrogen at 75 % of its price in such soluble nitrogenous manures as nitrate of soda and sulphate of ammonia. The phosphoric acid may be valued at half the price of soluble phosphoric acid in superphosphate. As regards the potash, it is present in the form of very minute particles of felspar, and 30 % of its price in ordinary potash manures may be considered approximate. In this manner the value of the deposit from a strictly manurial point of view is roughly as follows :—

			s. d.		s. d.		P.T.
Potash	(30% of		16 6)	=	5 0	=	24½
Phos. ac.	(50%	..	5 1)	=	2 6	=	12
Nitrogen	(75%	..	10 2½)	=	7 6	=	36½
				=	15 0	or	73 P.T.

or approximately 75 P.T. per feddan.

A glance at the analysis given will show that, as a general manure, Nile mud is poor in nitrogen, and this is entirely consistent with Egyptian experience as practically demonstrated in manurial trials. In potash, it is rich, and this is further confirmed by the result of actual trials for, generally speaking, unless under exceptional

circumstances this ingredient applied as a manures does not exercise any appreciable effect on Egyptian soils. As regards phosphoric acid we may affirm that the sediment is neither very rich nor is it poor; while in actual practice, phosphatic manures may be said to prove useful in the case of certain crops such as cotton, though their utility for many crops has not yet been demonstrated. That Egyptian soils are rich in potash is well known. If we accept that under ordinary circumstances ·25 per cent of this ingredient is sufficient for crops we may state that ordinary Egyptian soils are exceptionally rich. The fact that leguminous crops grow so successfully without manure is probably to a great extent accounted for by the richness of the soil in this ingredient together with the fact that lime also is generally present in ample quantities. Nothing could surpass the luxuriance of berseem (Egyptian clover). Though this crop is grown so extensively and removes from the soil more than 400 lbs. of potash and great quantities of lime in the three or four cuttings which are taken during the season from December to June, yet manures are never applied, in spite of the frequency with which it is grown.

It must be remembered, however, that in most cases berseem is eaten off and much of this potash and lime is almost immediately returned to the land in the dung and urine.

An indirect proof of the fact that nitrogen seems to be the controlling ingredient in Egyptian soils may be gathered from the fact that in the basins of Upper Egypt, two crops of wheat cannot as a rule be successfully grown in succession though with an alternation of beans or

berseem both of which remove more potash and phosphoric acid, but obtain a large quantity of nitrogen from the air, satisfactory crops are raised. This seems to confirm the results of the analyses of Nile mud already given which show the suspended matter of the river to be deficient in nitrogen.

The amount of suspended matter in Nile water varies from month to month, following practically the same curve as the height of the river. When at its lowest level in May, June, and July, the water is poorest in mud, but as the river rises so the suspended matter increases. This refers to observations taken at Cairo. As it takes a considerable time for the water to traverse the regions from the south, it follows that the increase in the suspended matter would take place a few weeks earlier in these regions.

During the years 1896-1899 the amounts of dry suspended matter per 100,000 parts of water were determined and found to be as follows:—

DRY SEDIMENT IN NILE WATER, PER 100,000 PARTS.

MONTHS	1896	1897	1898	1899
January	—	47·6	20·8	34·1
February	25·1	25·5	22·0	25·4
March	19·6	—	17·1	17·2
April	15·9	12·9	16·4	13·8
May	12·1	13·1	17·0	11·5
June	15·3	12·0	12·6	15·3
July	9·6	9·8	20·1	13·1
August	96·0	163·7	186·2	112·2
September	156·2	155·1	128·8	120·2
October	128·3	96·6	90·8	63·3
November	85·9	57·5	58·0	32·8
December	58·2	32·6	42·9	13·8

From the fact that the height of the Nile varies considerably from year to year it would be unwise to accept the figures given as absolute, yet they are sufficiently striking to show how the amount of suspended matter varies, generally speaking, with the height of the river.

The following table shows the composition of the sediment during the flood months, for the years 1898 and 1899 :—

COMPOSITION OF DRY NILE MUD DURING FLOOD.

	1898			1899		
	AUG.	SEPT.	OCT.	AUG.	SEPT.	OCT.
Insoluble matter and silica	57·20	59·38	55·92	57·49	56·08	56·14
Potash	·52	·53	·58	·50	·56	·49
Soda	·68	·65	·64	·48	·49	·51
Lime	3·71	2·49	3·64	3·07	3·02	2·68
Magnesia	2·53	2·66	2·52	2·76	2·79	2·56
Oxide of manganese	·24	·28	·23	·19	·28	·39
Iron oxide and alumina	25·69	24·90	26·91	25·44	26·22	26·39
Phosphoric acid ...	·29	·31	·30	·21	·19	·21
Carbonic acid ...	·91	·42	·63	·73	·84	·70
*Organic matter, etc.	8·23	8·38	8·63	9·13	9·53	9·93
*containing nitrogen.	·12	·13	·15	·17	·16	·23

During the months of August, September, and October, when the basins are filled, the average percentage of organic matter in the mud amounts to between 8 and 9% while during the three months of May, June, and July, when the Nile is at its lowest, it amounts to as much as 20% or more. That is to say, in respect of organic matter the suspended matter of the red water is poorer than that of any other time of the year. This is in accordance with what would be expected. When the Nile is low the small volume of water becomes contaminated with organic matter of various kinds but with the rise of the river the percentage of organic matter shows a rapid decline. Simultaneous therefore with the fall of the river we obtain an increase in the percentage of organic matter which reaches its maximum in June when the water contains a considerable amount of green vegetable matter which has accumulated chiefly in the region where the Gazelle river joins the White Nile and which is now brought down by first rains.

It is a matter of great interest to ascertain the richness of the suspended matter in nitrogen as the great differences of opinion which have arisen as to the general composition of the suspended matter of the Nile water have generally centred on this point. From the very nature of things we should not anticipate a very high nitrogen content. The organic matter has been transported an enormous distance in water at a comparatively high temperature where all the necessary conditions exist for its decomposition and decay and the consequent removal of a large portion of its valuable nitrogen.

During the months of low Nile, the percentage of

nitrogen in the suspended matter is high but as the river rises there is a remarkable drop. This is fully brought out in the following table:—

PERCENTAGE OF NITROGEN IN DRY SUSPENDED MATTER.

MONTHS	1896	1897	1898	1899
January	—	·17	·32	·18
February	·25	·25	·39	·30
March...	·31	—	·53	·32
April	·34	·57	·50	·52
May	·45	·51	·51	·64
June	·54	·83	·85	·84
July	·79	·65	·55	·74
August	·16	·13	·12	·17
September	·12	·14	·13	·16
October	·08	·12	·15	·23
November	·12	·18	·16	·24
December	·12	·22	·17	·35

From this it is seen that the percentage of nitrogen in the suspended matter during the months of August, September and October when the river is in flood, amounts on an average to approximately ·13 per cent, whereas during the months of low Nile immediately preceding the flood, it is five or six times as great. Taking the three flood months of August, September, and October, it is seen therefore that the nitrogen is lower than at any other period of the year, and is confirmatory of the fact that as a manure the sediment is comparatively deficient in this ingredient. The percentages of phosphoric acid and potash during the time of high Nile are not lower than at any other period and both are present in sufficiently large amounts

to lead us to anticipate that Egyptian soils would not, generally speaking, be deficient in these ingredients especially the latter. Actual experience confirms the result of the foregoing analyses, it being accepted that the soils of the Nile valley are more deficient it nitrogen than in any other ingredient while in potash they are generally very rich.

Farm-yard Manure.

As regards natural manures employed in Egypt the most important are farm-yard manure (sebach beladi), coufri, pigeon manure, marog, tafla, the remains of old houses, poudrette, refuse of slaughter-houses, etc., and the bye-products of abattoirs such as bones, dried blood, etc. The most important is undoubtedly farm-yard manure. This, in Egypt, as in most other countries, forms the basis of our system of manuring and it is only to be regretted that the available supplies are not greater.

The heaps which are seen around every village are evidences of the importance which the fellah attaches to its value, and it is recognised by every cultivator that whatever system of manuring be adopted it is absolutely necessary to periodically apply dressings of this fertiliser to maintain fertility. It has stood the experience of centuries and continues, and will continue, to be regarded as the backbone of manuring. From its very nature, farm-yard manure must contain all the elements of plant food, as the valuable part of it is itself derived from vegetable substances consumed as food by the animals producing it. The value of farm-yard manure is very variable and depends on such

a variety of complex circumstances that any figures given with reference to its composition can only be regarded as approximations. Its constituents are made up of (*a*) the solid excreta, (*b*) the liquid portion or urine and (*c*) the material employed as litter. It is evident therefore that its ultimate value will largely depend on the proportion in which these three different classes of substances are present.

The Solid Excreta.

The solid excrements of the different farm animals vary very much in composition, that is to say, in the proportion of nitrogen, phosphoric acid and potash which they contain. For example, the solid excrement of the sheep differs very considerably from that of the bullock and so on.

Other conditions, however, influence the composition of the excrement of any class of animal. A mere consideration of the nature of the solid portion will show that this must of necessity be the case. Roughly speaking, it is the undigested part of the food, that is to say that part of the food which has passed through the digestive system of the animal without being acted upon to any extent. Consequently, the nature of the food influences the composition of the resulting manure. We cannot therefore expect manure of equal value from an animal fed on a poor diet as from one fed on richer food, other conditions being equal. Thus, the value of the manure produced in Egypt by animals fed on a dry diet consisting of beans and straw is greater, weight for weight, than that produced when feeding on green berseem. In other words the more

nitrogen, phosphoric acid and potash contained in the food the richer will be the manure. Many other circumstances, such as the age of the animal, its condition, whether pregnant or not, etc., influence the composition of the resulting manure, but these are matters which do not call for detailed treatment here.

The solid excreta of our farm animals are distinguished from each other by the rates at which they ferment. For example, while that of the horse and mule ferments very rapidly and is known as "hot" that of oxen and buffaloes decomposes very slowly and is known as "cool". Sheep manure also ferments very rapidly, in fact it may be accepted that the lower the percentage of water in the manure and the higher its content in nitrogen, the more rapidly will it ferment. This principle is demonstrated in the formation of hot-beds, where sheep and horse manure are employed owing to the greater heat produced by their more rapid fermentation. Owing to these differences it will be gathered that a more regular fermentation is obtained when the manure of various animals is mixed together in one heap rather than when each is kept apart. The liability to loss by too rapid fermentation is in this way somewhat diminished.

Manure composed entirely of bullock and buffalo excrement will ferment gradually and act somewhat slowly in the soil, while sheep manure will be quicker in its action. As therefore, the value of the resulting manure is dependent on such a variety of circumstances it will be seen that it is extremely difficult to give analyses which accurately represent the composition of that produced by any class

of animal. The following, however, by Stockhart * may be quoted as typical of the various farm animals fed on a more or less dry ration :—

COMPOSITION OF SOLID EXCREMENT.

	Water	Nitrogen	Phosphoric acid	Potash
Cows	84	·30	·25	·10
Horses...	76	·50	·35	·30
Sheep	58	·70	·60	·30

It is probable that the excrement of bullocks is somewhat richer on an average than indicated above. Experiments by Lawes and Gilbert give the nitrogen in the solid excrement of an ox fed on straw, hay and beans as ·3 %, in that of sheep fed on hay as ·7 %; results which closely agree with the above. Storer † on the other hand states that the average of a number of analyses indicates ·48 % of nitrogen in cow manure. Taking the analysis of Stockhart as a basis it is seen that a ton of the solid excrement of the various animals contains as follows :—

CONTENTS OF 1 TON OF SOLID EXCREMENT IN LBS.

	Nitrogen	Phosphoric acid	Potash
Cows	6·72	5·60	2·24
Horses	11·20	7·84	6·72
Sheep	15·68	13·44	6·72

* AIKMAN'S "Manures and Manuring."
† STORER'S "Agricultural Chemistry."

From this it is gathered that the solid excrement of the sheep is much richer in nitrogen, phosphoric acid and potash than that of cows, while that of the horse is intermediate. The above figures refer to animals fed chiefly on dry food, a condition which prevails in Egypt during the summer and autumn months when the manure heap is largely made. During the winter and spring, animals are fed almost entirely on berseem in the field and their excrement is thus returned almost directly to the soil. It must be borne in mind, however, when considering the values of the manures of the various animals, that the quantity voided by one class of animal is much greater than that by another class, and that the bovine tribe compensates for the poorness of its excrement by the greater quantity voided. It is seen from the analyses given that the quantity of water contained in the manure varies with the kind of animal producing it, that of the bullock and buffalo being more watery than in the case of the horse and sheep. Buffalo and bullock excrements, when fed on berseem, contain respectively 87 and 84% of water while those of the horse and sheep contain 77%. When fed on dry food the percentage diminishes. For example with beans, tibn and cake the excrements of buffalo and bullock fall to 83 and 80% respectively. That of the horse fed on tibn and barley has 73% of water.

The figures given are borne out by practical experience in Egypt where the cultivator is well aware of the fact that sheep manure is weight for weight the most valuable, that of horses and mules being intermediate while that of bullocks and buffaloes is poorest.

The following table gives analyses of the dungs of the different farm animals on winter and summer rations.

ANALYSES OF EGYPTIAN DUNGS.

		Water	Nitr.	Phosp. acid	Potash	FOOD.
Winter.	Cow	84·5	·27	·22	·22	Berseem only.
	Buffalo ...	87·2	·31	·10	·17	Ditto.
	Horse... ...	77·7	·37	·30	·22	Ditto.
	Sheep... ...	77·5	·63	·41	·28	Ditto.
Summer.	Cow	80·5	·17	·16	·14	Tibn, beans, bran and linseed cake.
	Buffalo ...	82·8	·14	·14	·12	Tibn, beans, bran, and linseed cake.
	Bullock ...	79·3	·21	·21	·14	Tibn, beans and linseed cake.
	Horse... ...	72·6	·33	·32	·21	Tibn and barley.

These analyses show the composition of the solid excrement of bullocks and buffaloes fed on berseem to contain from approximately ·25% to ·3% of nitrogen with an average of about 86% of water. Calculated to dry matter this is equivalent to from 1·8% to 2·1% of nitrogen.

These results approximate to that of the solid excrement of Indian cattle by Dr. Voelcker.* This authority gives 1·34% of nitrogen in one air-dried sample containing 19·59 per cent of moisture. This, calculated to the dry state,

* VOELCKER'S "Indian Agriculture."

gives 1·66% of nitrogen, a figure slightly lower than those of Egyptian dungs given above.

Indian cattle dung is made, generally speaking, without litter and no attempt is made as a rule to save the urine. This difference in the amounts of earth (mineral matter) in the cattle manures of Egypt and India is sufficiently clear from a comparison of the following analyses showing the composition of air-dried manures.

	Egyptian	Indian
Moisture	20·75	19·59
Organic matter...	8·05	59·26
Mineral matter (ash)	71·20	21·15

The much smaller quantity of earth employed in Indian manure, is shown by the small percentage of mineral matter and the high percentage of organic matter in comparison will those of Egyptian heaps.

THE LIQUID EXCRETA OR URINE.

The urine of animals possesses a much greater value than their solid excrement. The latter as already explained consists of the food that has not been digested; the nitrogen, phosphoric acid and potash which were contained in the food and which were not capable of being absorbed into the animal system, are found here. On the other hand the urine contains those valuable ingredients which have been taken into the system, and after having been used

in the economy of the animal have been rejected. The animal has used some of the digested matter to build up its tissue, to make bone, etc., while the remainder is found in the urine. The quantity of urine voided will depend on the quantity of water consumed, but again, the more produced the poorer it will be.

The following analyses will give some idea of the composition of the urine of different animals (Stockhart).*

COMPOSITION OF URINE (per cent.)

	Water	Nitrogen	Phosphoric Acid	Alkalies
Cow	92	0·8	traces	1·4
Horse	89	1·2	traces	1·5
Sheep	86	1·4	·05	2·0

It will be seen from the foregoing, (*a*) that the urine shows considerable variations, is rich in nitrogen, and contains notable quantities of alkalies (potash), (*b*) that it is extremely poor in phosphoric acid, (*c*) that the urine of the sheep is, weight for weight the most valuable and (*d*) that the urines of the sheep and horse are more valuable than that of the bovine tribe. The animals in this case were fed on more or less dry food. The percentage of water in the urine of bullocks often amounts to 95 per cent. but sometimes falls to 88. The nitrogen is also often less than that indicated while sometimes it exceeds it. The

* AIKMAN'S "Manures and Manuring."

percentage of phosphoric acid (·05%) shown in that of the sheep is higher than that given by some authorities.

According to these analyses

1 ton of bullock urine contains 17·9 lbs. of nitrogen and 31·3 lbs. of potash.

1 ton of horse urine contains 26·8 lbs. of nitrogen and 33·6 lbs. of potash.

1 ton of sheep urine contains 31·3 lbs. of nitrogen and 44·8 lbs. of potash.

Munro * states that on an average 1 ton of the urine of the cow, horse, and sheep, contains respectively 30, 36 and 38 lbs. of nitrogen.

From what has preceded we may say:—

1. That in passing through the body of the animal, only a very small proportion of the original nitrogen, phosphoric acid and potash present in the food is retained; theoretically therefore, the manure should contain a large proportion of the fertilising matter which the original food did.

2. Taking the total amount of solid and liquid matter excreted, the latter (that is urine) contains more nitrogen; not only so, but the nitrogen in the urine being in a soluble state is the more valuable. The amount of nitrogen voided by an animal in the form of urine is much greater than that in the solid excrement.

3. Phosphoric acid is chiefly found present in the solid excreta, very little being present in the urine.

4. Potash is chiefly found in the urine. A glance at the figures showing the relative amounts of the valuable

* Munro's "Soils and Manures."

ingredients present in one ton of solid and liquid excreta respectively will clearly confirm the foregoing conclusion.

In order to make our comparison complete we may say that in the mixed excrement (solid and liquid) of the various animals we have the following percentage amounts of nitrogen and phosphoric acid (when fed on more or less dry food):—

	Bullock	Horse	Sheep
Water	84–86	75	67
Nitrogen	·35–·40	·65–·75	·91
Phosphoric acid	·09	·17	·15

In view of the fact that the valuable constituents are thus distributed, as already shown, in the solid and liquid voidings, the best results can only be obtained when both the solid excrement and the urine are found in the same heap.

It is clear from what has been stated that the first consideration upon which the value of the manure depends is the kind of animal producing it. The bulk of the mass is, however, composed of the litter used, and the value of this material must exercise therefore a very considerable influence on the nature of the whole. The chief objects of the employment of bedding are to supply comfort to the animal and to act as an absorbent for the urine. As most of the nitrogen and potash are found in the liquid manure and can only be retained in this way it is clear

that the power of absorption is the most important consideration in the choice of any material for this purpose. It also controls and regulates the fermentation of the whole mass. The nature of the manure heap in Europe when straw is employed is very different to that produced in Egypt where ordinary soil or Nile mud (chirb) resulting from the clearance of canals is used. A considerable part of the value attaching to the use of farm-yard manure in Europe arises from the effect it has on the mechanical condition of the soil, largely induced by the fermentation and decomposition of the organic matter which it contains. By the various complex changes which are set up, beneficial results follow, but an Egyptian manure heap from its nature is poor in organic matter. Analyses of fresh English farm-yard manure, composed of a mixture of that of the horse, cow and pig gave a total percentage of organic matter of 28% but a water content of 66%. Manure six months old gave similarly 16·5% of organic matter and 75% of water (Voelcker). Manure heaps in Egypt, however, only contain when comparatively fresh from 8 to 10% of organic matter and are thus relatively poor in this material. Old heaps only contain from 6 to 8%. It is needless to point out that the use of earth as litter, instead of some form of vegetable matter, accounts for this poverty. In a newly made heap of good manure in Egypt, the organic matter amounts to about 11 or 12%, though owing to fermentation this is reduced by one-third or even more. The heaps, however, are much drier, and in a fresh heap the water rarely amounts to more than 16% which is considerably reduced by age. As an absorbent and retentive

agent earth is excellent. It does not, however, enrich the heap to the same extent that straw does in European countries, and again it is much poorer in organic matter. It in fact dilutes the manure and thus renders it comparatively speaking poor. It is considered that the use of one ton of straw in Europe enriches the heap to the extent of 10 or 12 lbs. of nitrogen while an equal amount of earth in Egypt would similarly add only 2 or 3 lbs. There has been a tendency recently, however, in Europe towards the greater employment of straw as a feeding material and less as litter. In any case the use of straw from white cereal crops in Egypt is not to be thought of. An objection raised to the use of earth in Europe is that it is very difficult to preserve cleanliness. This would hold good especially in the case of dairy animals; with working bullocks, however, the objection does not arise. In India litter is objected to on the plea that the animals become infested with ticks. It is also stated that the cattle become unhealthy, a statement at variance with Egyptian experience. The only forms of straw occasionally employed as litter in Egypt are those of beans and rice. When removed from under the animal the manure is carted into loose heaps and exposed to the sun where fermentation takes place. Owing to the practical absence of rain, no loss is to be feared from the leaching effects of an excess of water falling on them, but on the other hand other losses occur which considerably detract from the value of the manure.

The precise nature of the fermentation and decomposition which takes place in a heap is a very complicated matter and depends on a variety of considerations. The active agents

are micro-organisms which exist in immense numbers and in great variety, the net result of whose actions is a partial breaking up of the complex organic substances into simpler forms. The exact nature of the changes which result as well as the rate at which they take place depends on a great many circumstances. In the first place the higher the temperature, the more rapidly does decay take place. Consequently, from this point of view, manure in hot and semi-tropical countries will ferment more quickly than in colder climates. Again, as fermentation is largely dependent on the action of organisms which require oxygen for their actions, the greater the surface exposed to the atmosphere and the more loose the heap the more rapidly will the manure decay. Decay is largely a process of oxidation and though in a heap of manure, organisms are found that can live in the absence of air, yet, it is through the action of that class that can only live in its presence that the final products of decomposition are chiefly formed.

The common practice of throwing farm-yard manure into small or more or less scattered heaps, covering a large space, which is prevalent in Egypt is not one to be recommended. When carted from the stable and thus loosely exposed to the sun and wind, there is a very rapid drying and considerable loss of valuable nitrogen. As the manure is removed almost daily, and not allowed to accumulate under the animals to the same extent as is often practised in Europe, the urine (which as already mentioned contains the bulk of nitrogen) is undergoing fermentation and the products of the change are to a considerable extent lost, largely in the form of the volatile carbonate of

ammonia. Even when allowed to remain in the stable there is loss, but when exposed to the sun and wind in small loose scattered heaps it must be very considerably greater. It is practically only the valuable nitrogen which suffers loss as the phosphoric acid and potash exist in more stable combinations. There can be no question but that the manure heaps should be made in a regular manner and in larger masses than are common. There should be as little surface exposed as possible, a condition which is evidently not secured when scattered about indiscriminately over a large area.

Again, fermentation is largely dependent on the dampness of the heap. In countries where the rainfall is considerable this acts in two ways, first by diminishing the temperature, and second by limiting the supply of air. In Egypt, heaps become very dry on account of the great heat and the large surface exposed. In order to prevent loss it is advisable that the surface of a heap be kept in a uniform state of dampness. In this way there would be less loss of nitrogen. Not only so but nitrification will take place more rapidly than in excessively dry heaps. Finally, as already mentioned, fermentation depends on the composition of the heap. The greater the proportion of sheep and horse manure the more rapidly will this take place; the greater the proportion of nitrogen present the more easily will it decay.

When farm-yard manure is thus kept in heaps for a considerable time a loss of weight takes place and a change in its composition. The latter arises chiefly from the amount of organic matter it contains, that is the excrement.

The result is that while there is an increase in the available plant food on the one hand, yet on the other, changes take place which are liable to cause a loss of valuable nitrogen. The organic matter of the solid excrement, that is to say, undergoes a slow change which renders its ingredients more available to the plant, while the urine ferments while still under the animals and gives rise to ammonia compounds, some of which are very liable to be lost. The chief result then of decay is that the organic matter is largely oxidised, the carbon is burnt away, the percentage of valuable ingredients concentrated, while in this country there is a considerable loss of water.

As regards the comparative values of fresh and old manures, the latter is weight for weight the more valuable. In Europe although rotten manure contains more water, yet the loss of organic matter not containing nitrogen, more than balances the gain, the net result being a concentration and an increase in value owing to the forms in which the valuable ingredients are present being more soluble and hence more available. In Egypt, however, there is on the other hand a loss instead of a gain in water and this would tend to render the difference more pronounced. The question of the relative value of fresh and old manure is, however, a complicated one, for we have to consider the loss which must inevitably take place during storage. What this may be depends in the first place on the manner in which it has been stored. By taking precautions it may be reduced to a minimum, while under careless treatment, it may amount in the case of nitrogen which is the most valuable ingredient to a very considerable proportion of the whole.

Probably the most satisfactory manner in which manure can be preserved is in pits. A few cultivators adopt this system and enrich the whole by the addition of sewage from mosques. The number, however, is only too limited. The pits should be tightly rammed at the bottom and covered at the sides with clay or some material which will harden. The whole should be kept moist, preferably by the addition of liquid manure, and frequently turned over to secure uniform fermentation. In this manner there would be a much smaller loss than takes place under the conditions usually prevailing.

The net result therefore of keeping manure for some time is a conversion of a considerable portion of the fertilising ingredients into more available and soluble forms, yet on the other hand there is a loss in the total amount of valuable ingredients and especially nitrogen, the extent of the latter depending on the care or otherwise with which the manure is preserved. In Egypt, as already explained, the manure heap accumulates chiefly during the summer and autumn months and is largely destined for cotton land to which it is generally applied in the month of February. As a general rule, it may be said the fellaheen do not keep their manure as long in the heap as the large cultivators. With a smaller area of land, they are more intensive cultivators and have a larger supply at their disposal, owing to the greater number of animals, relative to area, which they possess.

Fresh farm-yard manure is more forcing than that which has been stored for some time and while this may be no disadvantage for rapidly growing, leafy crops

such as maize, yet, for cotton, old manure is invariably preferred.

As regards the general composition of Egyptian manure heaps, treated in the ordinary manner and after exposure for six or seven months, the following may be taken as typical examples:—

	1	2	3	4	5
Organic matter	10·90	10·72	8·08	8·36	10·64
Nitrogen	·34	·42	·23	·20	·30
Phosphoric acid	·20	·22	·19	·20	·20
Potash	1·23	1·84	1·56	1·34	1·04

It may be assumed, generally speaking, that the average content of nitrogen, phosphoric acid, and potash is respectively ·3, ·2, and 1·5%. On this basis a ton of manure contains approximately 7 lbs. of nitrogen, 4 ½ lbs. of phosphoric acid and 33 lbs. of potash ; while an application of 10 tons, a good average dressing employed for cotton, would add to the soil 70 lbs. of nitrogen, 45 lbs. of phosphoric acid, and 330 lbs. of potash.

It has already been pointed out that farm-yard manure as employed in Egypt is poor in organic matter in comparison with that in European countries where vegetable matter of some nature is generally used as litter, while again it is low in water content. The quantity of moisture varies greatly according to the age of the manure but in England it varies from 65% in fresh to 80% in

rotten manure. In Egypt from 7 to 8% may be taken as an average of old manure. Calculated to dry matter, English manure heaps contain about 14% of organic matter and Egyptian heaps similarly 8 or 9%. The former contains in one ton from 9 to 15 lbs. of nitrogen, about the same quantity of potash, and from 4 to 9 lbs. of phosphoric acid (Warington).* Egyptian farm-yard manure is thus poorer in organic matter, nitrogen and phosphoric acid but much richer in potash. In one ton the nitrogen is equivalent to approximately 45 lbs. of nitrate of soda, the phosphoric acid to 27 lbs. of super-phosphate (16-18% soluble) and the potash to 61 lbs. of purified sulphate of potash. That a value attaches to such bulky substances in addition to what is actually represented by the percentage of valuable ingredients they contain has already been referred to, and an application of chemical manures containing equal amounts of nitrogen, phosphoric acid and potash would by no means have the same ultimate effect in the soil.

It is a fact well recognised by native cultivators that a dressing of farm-yard manure is periodically necessary to keep up and maintain the fertility of the soil. Coufri, which will be referred to later, is extensively employed for maize, grain, and other crops, but it is accepted that a continuation of its use rapidly reduces the condition of the soil and good cultivators are adverse to its too extensive employment. In cotton cultivation, the employment of farm-yard manure is attended by most satisfactory results.

* WARINGTON'S "Chemistry of the Farm."

On the other hand, a too liberal use of the latter is not conducive to the best results. Some years since, when the question of manuring began to attract greater attention, many cultivators employed excessive quantities on their cotton crop with results which were by no means satisfactory.

Farm-yard manure in Egypt is almost invariably applied to the crop for which it is intended before sowing, though occasionally a small quantity is added to the cotton crop and hoed in during the early stage of growth. As a rule, however, the manure is carted on to the land before the last ploughing in preparation for the crop, and then ploughed in. The nature of the native plough is such that the fertiliser is not buried deeply. As regards the methods of application there are three in common use:—

(*a*) Placing the manure in small heaps in the field, allowing it to remain some time and then distributing.

(*b*) Distributing over the land and allowing it to remain some time before ploughing in.

(*c*) Distributing and ploughing in at once.

There can be no doubt that the last plan is the best. By allowing the manure to remain in heaps exposed to the sun and wind, loss of nitrogen takes place and the subsequent distribution is not even. The portions where the heaps have been are too heavily manured, and others too lightly. Distributing over the land without ploughing in means loss, and the safest plan is to distribute and plough in at once.

When removing from the heap, it is found that a

considerable part of the manure is caked together and it is always advisable to break up these lumps, otherwise they will resist fermentation in the soil for some time. Were manure stored in pits and turned occasionally this would not be seen as the fermentation would be more even.

As in India, the practice of burning cattle-dung as fuel exists in Egypt, and in every village a considerable proportion of the excrement is so employed. Not only so, but in the neighbourhood of large towns we find a considerable trade is carried on in these "gillahs" or sun-dried cakes. It is naturally only the poorest classes who resort to this, the reason for its adoption being a scarcity of fuel. No wood is available in Egypt and the price of coal places it entirely outside the reach of the lower classes. During the autumn and winter months maize stalks and cotton-wood are extensively employed, but during the rest of the year sun-dried manure cakes form the bulk of the fuel. It is doubtful whether the great loss which thus naturally results to agriculture is fully appreciated, or even thought of, but when we reflect on the amount of nitrogen lost in this manner annually we can see at once that it must reach a value which, if capable of estimation, would represent a very considerable sum. It is almost unnecessary to state that by the process of burning the nitrogen contained in the manure is lost, though if the resulting ashes be returned to the manure heap the phosphoric acid and potash are preserved. The most valuable constituent, and the one which is the most costly to replace, however, disappears.

In ordinary air-dried Egyptian cattle manure the

percentage of nitrogen amounts to 1·4 per cent. In the sun-dried cakes the percentage is slightly increased owing to the greater degree of dryness obtained and the percentage of nitrogen may be stated as 1·5%. In one ton of "gillahs" there is consequently 33·6 lbs. of nitrogen, practically the whole of which is lost in burning. In order to replace this nitrogen it would be necessary to purchase 215 lbs. of nitrate of soda which at prices prevailing in Egypt is equal to an expenditure of at least P.T. 125. It is seen therefore that the loss is not a slight one and it is certainly not a matter of indifference to cultivators. Not only is it the loss of nitrogen which has to be considered but also the loss of organic matter which we have already pointed out as being so necessary for Egyptian soils. Until a better supply of fuel is available it is difficult to see how this wasteful practice can be prevented.

Pigeon Manure.

This is very extensively used in this country, more especially in Upper Egypt, and constitutes a rich manure. The excrement of all birds forms a valuable fertiliser, and that of fish-eating birds that has accumulated on the coasts of Chili, Peru, etc., has been used in Europe for nearly a century under the name of "guano." Pigeon manure is used for melons, vegetables and other valuable crops as well as for sugar-cane. It is too costly a manure to be employed generally for ordinary crops. It contain about 5% of nitrogen, or 15 to 20 times more than that in ordinary sebach beladi. It also contains notable quantities of phosphoric acid, amounting to 2·25%. The following table

shows the comparative richness of pigeon manure and ordinary sebach beladi, each calculated to 5 % of moisture:—

Pigeon Manure compared with Sebach Beladi.

	Pigeon manure	Sebach beladi
	%	%
Nitrogen	5·0	·30
Phosphoric acid	2·25	·20
Potash	2·70	1·5

Pigeon manure is therefore at least 15 times richer in nitrogen, 10 times as rich in phosphoric acid and twice as rich in potash as sebach beladi. It is sold by the ardeb of 145 kilos, the price varying, generally speaking, from 40 to 50 P.T. per ardeb. This is equivalent to about P.T. 315 per ton. As much as 7 ardebs is sometimes used per feddan. It decomposes quickly in the soil and is therefore very suitable for those crops which do not occupy the land for a long period. Though comparatively speaking a rich manure it is far less so than good guanos.

Nitrogenous manures employed.

Coufri.

Two natural nitrogenous manures are largely used in Egypt, viz:—"Coufri" and "Tafla." While the former is extensively employed both in Upper and

Lower Egypt, the use of the latter is confined to Upper Egypt.

With the exception of ordinary farm-yard manure, coufri is generally speaking the most important natural manure at the cultivator's command, and finds a most important place in the agriculture of the country. It really consists of the remains of ancient villages, mixed with debris and organic matter of various kinds. These mounds, scattered over the whole country, are generally of great age, and having accumulated in a climate which is more or less rainless, there has been but little loss of valuable matter. Through the length of years which have elapsed, the organic matter has undergone decomposition and decay, and by the process known as nitrification, the nitrogen of the organic matter has become largely converted into soluble nitrogenous compounds, which we now find in the so-called sebach coufri. It is impossible to estimate the great quantities which existed in such natural mounds, but it was certainly enormous and has formed for many decades a valuable supplement to the farmer's manure supply. As would naturally be expected, however, the best heaps are being rapidly used up and cultivators have to go further afield to obtain good supplies. The day must naturally come, in fact is rapidly approaching, when, the better quantities having become exhausted, the poorer mounds will not bear the cost of transport for the long distances which will become necessary.

At present immense quantities of coufri are carried from the large mounds to less favoured localities; in some cases the material is transported for very considerable distances.

boats being extensively employed as well as railway transport.

As the supplies diminish the cost of transport becomes an ever increasing one. For more or less short distances camels and donkeys are employed, and the cultivator possessing such animal transport does not allow the labour of such animals to enter into his cost of manuring.

The natural material is generally roughly sieved before transport, to remove broken pieces of pottery, stones, &c., which are almost invariably mixed with it. It is difficult to arrive at the cost of manuring with coufri owing to the fact that while some localities are specially favoured, others are placed at a disadvantage. An ordinary dressing of about 10 tons per feddan for the maize crop costs at least from 100 to 150 P.T. per feddan but generally more.

Coufri is valuable chiefly as a nitrogenous manure, and this ingredient exists largely in a soluble form. It has thus naturally resulted that it is most extensively used for quick-growing leafy crops, such as maize, sorghum, cereals, &c., rather than for cotton, though very considerable quantities are used for the latter crop. It is also used largely for vegetables, and extensively in Upper Egypt for sugar-cane. We may say in fact that it is used for all crops, more or less, but in some cases with greater success than in others.

Its percentage of total nitrogen varies from as much as ·75%, in exceptional cases, to less than ·2% in very poor samples. It is evident therefore that its value as a manure varies greatly, and some heaps cannot with advantage bear the cost of transport.

Of phosphoric acid it contains from less than 1 % to as much as 1·75 % in exceptional cases; and of potash from 1 % to over 2 %. We may, say, however, generally speaking, that it is as a nitrogenous manure that coufri is employed, and that its value is mainly in proportion to the percentage of this ingredient which it contains.

The following table shows the composition of various samples, according to recent analyses, which have been made in the Laboratory of the Khedivial Agricultural Society by Mr. Hughes.

ANALYSES OF EIGHT RECENT SAMPLES OF COUFRI.

Total nitrogen	·42	·718	·296	·190	·190	·235	·156	·370
+ Nitric nitrogen ...	·112	·178	·153	·121	·126	·227	·058	·238
+ Equal to sodium nitrate...	·68	1·046	·931	·737	·761	1·38	·350	1·44
Common salt	2·72	3·51	·970	·500	2·17	3·80	·650	2·25

The variable nature of the manure will be observed from these figures, and it will be readily understood how much more valuable some mounds are than others. In fact this is so marked that it is always advisable, before using any heap to ascertain its composition, in order to avoid the transport of a mass of material which in many cases can never repay the cost.

From the analyses it will be seen that the amount of soluble nitrogen in coufri is, approximately speaking, equivalent to 1 % of nitrate of soda. In other words for every

100 kilos of coufri employed one kilo of nitrate of soda is added to the soil.

One great objection to the employment of many mounds is their high content of sodium chloride (common salt).

In many districts the continued use of coufri has been attended with disastrous results to the soil, and salt efflorescences have appeared to such an extent that the land has considerably deteriorated and a discontinuance of the use of the manure has naturally resulted.

Samples have been found which contain in some instances as much as 5% or more of common salt, and an application of say 10 tons containing this percentage to a maize crop would add to the soil 1120 lbs. of common salt. The want of drainage, which is often felt in Lower Egypt naturally aggravates this evil, whereas in Upper Egypt, where drainage is better, the ill-effects are not so apparent.

The following recent analyses of Lower Egypt heaps, show the excessive percentage of salt sometimes present:—

	No. I.	No. II.	No. III.	No. IV.	No. V.
Nitrogen	·36	·12	·13	·37	·14
Phosphoric acid	·54	·76	·23	·83	·43
Potash	·23	·32	·10	1·58	1·04
Sodium chloride	2·91	4·80	9·40	2·52	2·56

The average content of common salt in the 8 samples recently analysed in the laboratory of the Society is 2·07.

An application of 10 tons of coufri therefore would mean the addition of 463 rotls of salt per feddan.

The quantity of nitrogen found in an organic form in coufri varies considerably, the higher percentages probably indicating that the mounds are of more recent origin that those in which a practically complete decomposition of the organic matter has taken place. An examination of the 8 samples recently analysed will show that while in some cases the amount of soluble nitrogen present amounts to one fourth of the total nitrogen present, yet in others almost the whole of the nitrogen present is in a soluble form.

It may be stated generally that only about 3% of the transported material possesses any manurial value, and that 97% consists of more or less worthless matter.

If we assume on an average that coufri contains 1% of nitrate of soda, then every ton of coufri added to the soil means an application of 10 kilos of nitrate of soda. An ordinary dressing of 10 tons therefore is equivalent to the employment of 100 kilos of nitrate of soda. In this dressing of 10 tons which is a common one for the maize crop, the soil would perhaps receive 110 lbs. of phosphoric acid, and 200 lbs. of potash.

The percentages of these ingredients present are however very variable, and though the phosphoric acid and potash form valuable additions to the soil, yet it is the available nitrogen which exercises the greatest effect, and this is seen by the fact that an application of coufri to a quickly growing crop such as maize has a more immediate effect than farm-yard manure, though the latter has a

greater after-effect. The phosphoric acid and potash are not present in a readily available form.

To find sufficient quantities of farm-yard manure for the maize crop is quite out of the question and under actual conditions it is considered preferable to use coufri for maize, and to reserve the whole of the cattle manure for cotton. As far as the maize and cereal crops are concerned coufri exercises a more marked effect, and it is becoming more fully recognised that farm-yard manure is employed to greater advantage on the cotton crop and there is an increasing tendency to apply less of it to maize and other crops.

The question arises as to the relative values of coufri employed as such, and nitrate of soda and sulphate of ammonia employed in quantities containing an equal amount of nitrogen. It is impossible to decide except by direct experiment what percentage of the total nitrogen in the coufri is recovered as increased crop, compared with nitrate of soda or sulphate of ammonia, and which manure may therefore be employed with the greatest advantage. In making a comparison with coufri and soluble nitrogenous manures no value has been attached to the phosphoric acid and potash which coufri contains, but on the other hand, the salt content of the latter must not be lost sight of, for even in the case of those mounds which are not absolutely injurious it is advisable to restrict the amount applied, for cultivators are fully aware of the fact that to continually apply coufri often results in deterioration of the land.

The considerable accumulation of phosphoric acid and

potash, which must take place in the soil through heavy dressings of coufri is a fact worthy of notice. The berseem crop, which often follows maize, makes very considerable demand on these ingredients, especially potash.

The latter is particularly necessary for such crops, and under the basin system of irrigation, the land receives considerable quantities annually, and there can be no question as to its sufficiency for all crops. In Lower Egypt, however, the extensive growth of berseem, which contains in four cuttings approximately 400 lbs. of potash, removes enormous quantities of this ingredient. Egyptian soils are, as already mentioned, rich in potash. Farm-yard manure also returns a great quantity of potash to the soil. That these two fertilisers, farm-yard manure and coufri together, provide the soil under ordinary conditions with a sufficiency of potash, or that the soil is amply provided with this necessary food, is to a great extent confirmed by the small effect which potash manures exercise when applied in artificial fertilisers. Phosphoric acid seems to be present naturally in the soil in considerable quantities, but great differences exist as regards its solubility in different districts.

Summarising, we may say that the value of coufri depends almost entirely on the nitrogen it contains. It contains both phosphoric acid and potash which the average Egyptian soil does not, generally speaking, stand in immediate need of. The additions of these ingredients, however, cannot fail to have a beneficial effect. The presence of salt in coufri is a great disadvantage to its

continued employment as a manure, especially so when it is present in excessive quantities as is the case with a great number of mounds.

Tafla.

The presence of tafla is confined entirely to Upper Egypt, where it exists in a natural state, and provides a very large amount of manure of a valuable nature. It is a nitrate-bearing clay, found in the desert hills in the southern provinces.

It is usually a bluish clay, though sometimes a marl, containing varying proportions of nitrogen in the form of nitrate of soda. It occurs chiefly south of Keneh, in fact north of this it seems to be practically unknown. Beyond Keneh, however, it exists in large quantities and is in common use, except where good coufri mounds are found in close proximity to the land.

On the basin lands of Upper Egypt the question of manure supply has not attained that importance which it has assumed in Lower Egypt, or on perennially irrigated land. The interdependence of water and manure has already been referred to. It may again be stated that the supply of the one without the other can only be attended with a limited amount of success.

Where we have rich virgin land, water alone for a time may be sufficient, and where the soil receives annually a good layer of mud, manure may be to a very great extent, and perhaps entirely, dispensed with. Any exten-

sion in the supply of water, however, necessitates an increased supply of manure, and this can be amply illustrated in Upper Egypt. The extension of perennial irrigation in that region will undoubtedly call for an increase in the supply of manure.

In places a considerable portion of the basin lands receives manure. Wherever artificial watering is resorted to, either by wells or direct from the river, it is found that manure is necessary to produce full crops. In the most southern provinces, where the basin land is of poorer quality, it is found more profitable to water and manure, rather than to grow the cereal crops trusting only to the water received from the flood. In the provinces of Upper Egypt, considerable areas of qedi or summer dourra (sorghum) are grown, which in the basin lands is off the land, before the arrival of the flood, and which is followed by the ordinary winter crops. As a general rule it may be said that this crop is always manured.

Ordinary maize is also grown in the northern provinces on basin lands which are high, or protected by small dykes, in such a manner that it does not become flooded until late, when the crop is practically ripe. This crop is also heavily manured.

We may say therefore that when water is artificially employed, that is to say on the whole of the perennially irrigated lands or when used on land actually under basin irrigation, manure is required.

In the southernmost provinces of Assouan and Keneh the manure question is of very considerable importance.

The basin lands here are of poor quality, and as already mentioned, the flooding has often to be supplemented by artificial irrigation, and shadoofs fringe the river in considerable numbers. On land which is not flooded, the winter crop is preceded by sorghum, and is heavily manured, in fact the system of cultivation adopted is very intensive.

In the neighbourhood of Assouan, and for about 40 or 50 kilometres to the north, basin irrigation is not adopted on a large scale, and the manure in common use is that known as coufri, which has already been dealt with.

As we go north, however, this is very largely replaced by tafla, which is extensively used for millet, and for the irrigated winter crops (barley and wheat) as well as for sugar-cane.

As therefore the summer crop is manured, and also often the winter cereal crop, it follows that the agriculture of this tract is largely dependent on the manure supply.

Tafla, as already mentioned, does not occur to any great extent north of Keneh, but south of this it is very common. The supply of natural manure is very limited, cattle are few in number, and berseem is not grown to any extent. As soon as the winter crop is off the land, the cultivators occupy themselves with the transport of tafla from the neighbouring hills. From the nearest hill the material is transported by the cultivator himself by means of his own camels and donkeys, but from the more distant spots the manure is carried to the river,

where it is sold and transported by boats to less favoured districts.

A company is at present engaged in transporting the manure to the river bank by means of a light railway at Sabaieh.

As regards the nature of the manure it may be said that it is entirely nitrogenous, and is in many respects similar to coufri. It is, however, not in such a fine state of division.

Extending as it does over such a large area it is not surprising that it varies very much in composition, some samples being practically worthless, while others are correspondingly rich.

Many analyses were made some years ago, which showed that the proportion of nitrate of soda present varied from as little as 1% to as much as 16%. The question is of course largely one of transport, a poorer sample near being perhaps of greater value than a richer one very remote. The material varies from a light grey or brown to a slaty colour, shaly or crumbly in nature on the surface and very compact. It is capable of being easily ground. It may be said to vary from a clay to a marl or even in cases to an argillaceous limestone, depending on the amount of carbonate of lime present. As would naturally be imagined, the richest material is found on the surface, where the nitrate of soda has been brought up by capillarity, while that lower down is poorer.

So much is this the case, that in some places the material contains as much as 24% of nitrate at the surface, while at a depth of 30 centimetres analyses show only 3%.

It can readily be understood that cultivators are willing to transport the richest qualities at considerable expense while others will not bear the cost of being carried any great distance. When brought into contact with water, the material rapidly crumbles down.

Natives remove the tafla from the surface where it is rich and called "hamed" leaving what is poor or "berd." After being left a certain time they return to the original place and again remove the surface, which has now been changed from "berd" to "hamed," by the bringing up of salts from below by capillary attraction.

It seems, according to investigations made some years since, that, quarrying in bulk at a distance of not more than a few kilometres from the river, it would not be possible to obtain material possessing a greater average nitrate content than 5%. It is seen therefore that the material known as tafla, and used so extensively in the southern provinces of Upper Egypt, is really nitrate of soda in an impure form, mixed with varying quantities of clay and limestone. In addition, other salts are present, viz: common salt and sodium sulphate; this however will be referred to later. At the time when the question of the use of tafla was causing considerable discussion, the possibility of profitably extracting nitrate of soda in a pure form was discussed, it being thought by some that the pure salt could then be used by cultivators without having to transport such a great bulk of useless material at the same time. The question of being able to export nitrate was also considered.

It would be out of place here to enter into the various questions involved, such as the cost of evaporating the solution of nitrate of soda and other salts which would be obtained by treating tafla with water, but we may state that the relative poverty of the material does not hold out much hope that the process could be profitably conducted.

From calculations which were made it appears that the cost of transport amounted to an equivalent of about Lst. 5 per ton for nitrate of soda though at present it probably amounts to more. There can be no doubt that the use of the commercial material would save a considerable amount of time and trouble, but it costs at least L.E. 11 per ton to import. We see therefore that cultivators are really obtaining nitrate of soda at a cheap rate, in fact much below commercial value.

The one great drawback, however, is the fact that tafla contains considerable and generally excessive quantities of common salt and sulphate of soda. These salts are often present in very large quantities. Continued use of such material on any but basin lands would have a deteriorating effect on the soil, and for this reason it has been objected to by some as a manure for cane.

Summarising therefore, we may say that tafla is valuable on account of the nitrate of soda it contains, the latter varying from as little as 1% to as much as 16%. Of other valuable ingredients it contains but insignificant quantities, that is to say of phosphoric acid and potash. It contains however large quantities of salts.

Analyses of 8 recent good samples made in the labor-

atory of the Khedivial Agricultural Society by Mr. Hughes gave the following results:—

Common salt	6·25	3·97	4·92	5·88	9·24	3·97	4·92	5·88
Sodium sulphate ...	3·84	1·16	2·74	5·28	4·12	1·16	2·74	5·28
Nitrate of soda... ...	9·13	6·80	9·02	4·42	9·01	6·80	9·02	4·42
Total salts	19·22	11·93	16·68	15·58	22·37	11·90	16·68	15·58

These good samples show an average content of nitrate of soda of 7·32% out of an average content of total salts of 16·24%, the remainder being chiefly common salt and sodium sulphate. Many samples are almost worthless, being of a hard shaly nature, while the best samples analysed contained 16·91% of nitrate of soda.

The price paid per ton for the material varies considerably with the distance transported, but taking into consideration that the richer the sample is, the greater distance it has to be transported, the price as a rule tends towards a certain uniformity per cent. of nitrate content. Average material containing 5 or 6% of nitrate of soda costs, delivered on the land, approximately 40 P.T. per ton, and as much as L.E. 2 or L.E. 3 is sometimes spent for manuring a feddan. A price of 40 P.T. per ton for material of the nature indicated, is equivalent to about 650 P.T. or 700 P.T. per ton for pure nitrate of soda.

This is less than the price of the latter which in Upper Egypt would cost L.E. 12 per ton.

On the other hand the injurious effects of the salts present in the tafla have to be considered as well as the fact that the continued use of this manure leaves a considerable quantity of stony material on the land, and considerably hardens the soil. On several occasions the question has been discussed as to whether it would be advantageous to transport tafla to Lower Egypt. Unless the material can be found in bulk of a much better quality than that actually being used, it would not be profitable to do so.

Marog.

The uncultivated land situated between the river and the hills in Upper Egypt, between Luxor and Assouan, is often covered by a deposit of material possessing considerable manurial value. This material, which is known as "marog" is extensively employed for manuring the millet and cereal crops. The plains have been more or less dug over by small cultivators, and an immense number of donkeys and camels may be seen transporting this material to the fields.

It is probable that the surrounding hills being rich in tafla the salts have been brought down by rain and distributed there over the plains. The material consists of earthy matter mixed with salts in various proportions.

The salts present consist of chloride, sulphate, and nitrate of sodium. It is to the presence of the last named that the manurial value of the material is due.

It is as a rule richer than coufri, as the following analyses from the plain of Kom Ombo will show.

ANALYSES OF MAROG FROM KOM OMBO PLAIN
(Khedivial Agricultural Society Laboratory)

Moisture	4·60	3·97	6·21	3·50	3·34
Organic matter	10·41	14·56	8·52	9·61	11·30
Soluble salts...	10·28	10·28	8·46	8·86	10·23
Chloride	3·19	4·09	3·35	3·56	4·41
Nitrate	5·92	4·88	3·67	3·52	4·22
Noxious salt...	4·36	5·40	4·79	5·31	6·01

These analyses show that "marog" contains a higher percentage of nitrate of soda than ordinary coufri; the average of the five analyses given being 4·44% while coufri only contains from 1 to 2%.

MINOR MANURES.

A gratifying feature of the past few years is a tendency on the part of Egyptian agriculturists to utilise material which previously did not attract their attention, and consequently we have many products, which though not great in quantity individually, yet in total will eventually reach a considerable amount.

Such manures are those derived from the sewage, etc. of houses and mosques, and from the wastes of the slaughter houses, *e.g.* dried blood, bone meal, powdered horn, etc. Every encouragement and facility should be given for the production of such fertilizers, for not only do they provide

the agriculturist with organic manures which are greatly needed, but the disposal of some of them is of great importance from a sanitary point of view. It is only a few years since these products were not deemed worthy of attention, but the demand which has arisen for manure has brought into existence a local trade in these minor products. A valuable manure which has not yet been put on the market is fish guano, which is extensively manufactured in Norway and exported to various parts of Europe. It is also manufactured to a lesser extent in other European countries and America. As its name indicates it is produced from fish which are useless for market purposes, and from fish refuse. It is a valuable fertiliser, the best qualities containing from 8 to 10% of nitrogen, while the phosphoric acid varies from 7 to 15%. The presence of oil impairs its value as a manure, retarding fermentation when it is applied to the soil. It is generally made into a compost with other manures before being used, while sometimes the fish refuse is pressed under heat to extract the oil which it contains, and then subsequently reduced to a fine dry meal in excellent condition for agricultural use. There must be a considerable amount of fish refuse in the neighbourhood of Lake Manzaleh, and at Alexandria, but whether in sufficient quantity to render the production of fish guano possible is not quite clear.

The first concession accorded by the Egyptian Government for the disposal of sewage, was in the year 1882, and was extended to Cairo and Alexandria only. Under the terms of this concession, which was for 40 years, the material was to be carted to filter-beds, and a portable

manure made. At the expiration of this term the whole installation became the property of the State. A company with a capital of L.E. 40,000 was floated, but three years subsequently it was remodelled under the name of "La Société Générale Egyptienne d'Engrais." The enterprise was not, however, successful. In the year 1896, by Khedivial Decree, a second company was formed, under the name of "La Société Générale Egyptienne No. 2." This company shared the fate of its predecessor, and in 1897 a new company under the name of "The Cairo Sewage Transport Company, Ltd." was formed, which has met with success, and continues to furnish to agriculture considerable quantities of various products annually.

The failure of the previous attempts appears to have been due to faulty administration, and to the fact that cultivators were not at that time sufficiently alive to the benefits to be derived from manures, other than those which existed naturally in the country.

The value of sewage as a manure has given rise to much discussion in the past, and at one time there was a great tendency to overestimate its value. Under the conditions existing in European cities, the chief points concerning it are its great quantity and its poor quality. By the use of enormous quantities of water the excrementitious matter is greatly lessened and the matter is regarded rather from a sanitary than a manurial point of view. A ton of sewage in European cities only contains 2 or 3 lbs. of dry matter, the total nitrogen is but a few ounces, while the phosphoric acid is even less, the value of the whole being from ½ P.T. to 1 P.T. per ton. Two methods are generally

employed for its utilisation. The first is sewage irrigation, by means of which it is poured on to the land which is specially arranged for the purpose. The second is that known as precipitation, etc. In Egypt where no system of drainage exists and the material is removed from cess-pits by means of pumps, the latter only is used.

Mechanical filtration removes the insoluble suspended matter which it contains, and the medium usually employed is charcoal, either alone or mixed with sand, burnt clay, etc. By chemical filtration, however, practically the whole of the phosphoric acid is removed, and of all substances employed lime is probably the most common on account of the ease with which it can be obtained and its low price. While the substance as obtained contains a very large proportion of the phosphoric acid of the sewage, the nitrogen and potash present in the liquid part are not retained. In addition to lime, a great many other substances are employed, either alone or in conjunction with it or with one another. Sulphate of alumina, perchloride of iron, sulphate of iron, etc., etc., are employed, and in a well known process, the A. B. C., a mixture of various proportions of alum, charcoal, clay, lime, blood and alkalies is used. Only partial purification, however, is obtained. The sludge was at first allowed to dry by exposure to the atmosphere, but rapid decomposition was set up and the filter came into use which at once removed a very considerable amount of the water. As regards the actual manurial value of the sludge, considerable differences of opinion exist, and to its physical character have been attributed the poor results which have been obtained. The

chief difficulty in making a portable manure from sewage may be said to be the failure to extract the nitrogen, which is the most valuable constituent it contains.

The sewage manures made in Egypt form a useful and valuable supplement to the inadequate supply of farm-yard manure at our disposal. Though not actually rich, comparatively speaking, in fertilising ingredients, they are much more so than our ordinary manure, and they contain large quantities of organic matter whose beneficial effects on the soil have already been dealt with. From the large towns, the contents of cess-pits are, as already explained, removed by specially constructed carts to large filter beds, where a portable manure is produced. The food of man having been originally derived from the soil the total loss of fertilising ingredients, owing to the non-return of sewage to the soil, must be great, for it is a very small proportion of the total production which finds its way back to the land again, and the arrangement for the disposal of sewage in European countries prevents more than a mere fraction of it from ever being returned to the soil. The annual value of the material carried into the rivers and the sea thus represents an enormous sum. The material removed from European houses in Egyptian cities is very poor, owing to the large quantities of water present, while that obtained from mosques and dry closets is much richer. The climate is particularly favourable for the production of portable manures from sewage on account of the proximity of the desert, the rapid evaporation which takes place, and the low price of labour. The great obstacle to the production of a rich manure is

the fact, already mentioned, that the nitrogen is contained in the urine, which is almost entirely lost. A certain quantity remains, and in order to prevent the loss of this by fermentation, and at the same time to help to deodorise the whole, gypsum, (sulphate of calcium) is added. This is used in Egypt on account of its low price (80 P.T. per ton).

The drying of the sewage should take place as rapidly as possible to prevent fermentation. For this reason, the area of the basin in which the sewage is placed should be of sufficient size that the daily loss by evaporation is equal to the quantity of liquid added. The basins are shallow: if deep, much material is stored, and consequently a long time is required to dry and to manufacture. In Cairo, the sewage is first discharged into distributing basins which are at a slightly higher level than those for evaporating, and are provided with iron gratings: workmen rake over the material to remove foreign matter, stones, etc., the latter being carted away. The sewage is pushed through the evaporating basins and during the days of filling, as well as during the first five days of drying the gypsum is added, which helps the process. When sufficiently dry, the material is removed and transported to be spread out to further dry. The product is sold under the name of "Matières Premières" at about P.T. 65 per ton, and contains:—

Nitrogen	1·50%
Phosphoric acid	1·75%

Better qualities may contain 1·75% of nitrogen, 2·5% of phosphoric acid and ·5% of potash.

These qualities are sold for 75 P.T. per ton.

The longer the material is allowed to remain the drier it becomes, and consequently relatively richer. When quite dry, ground up and sieved, it is sold as "Poudrette," at the rate of 110 P.T. per ton for the quality known as "best." The composition of this material is as follows:—nitrogen, varying from 1·75 to 2%; phosphoric acid about 3%; and potash about ·5%. When purchasing, a guaranteed analysis is obtained. The material is sold loose in order to economise sacks. A quality of poudrette known as "best best" and containing 2·25% of nitrogen is sold for P.T. 125 per ton.

The prices at which these manures are sold are considerably below those at which they are offered in European countries, and it is to be regretted that the quantities produced are so relatively small. As organic manures, they are valuable for the general improvement of poor soils, and when enriched by the addition of chemical manures may with advantage be used for any crop. They decompose somewhat slowly in the soil and after the removal of the crop, leave a considerable amount of residue. The best kinds of poudrette are well able to bear the cost of transport, but the production is only 500 tons per year, while of the Matières Premières about 1500 tons are produced. There is a considerable quantity of inferior material, mixed with earth, stones, etc., which though useful on poor soils, wanting in humus, can scarcely bear the cost of transport for a considerable distance.

In addition to poudrette, various other manures are sold by the Cairo Sewage Transport Company, Ltd. The refuse

from slaughter-houses, which in the past was allowed to accumulate and endanger health is now mixed with sifted coufri, and the resulting manure sold under the name of "Matières Abattoirs" while the refuse from tanneries at Old Cairo, treated in a similar manner, is sold as "Engrais des Tanneries." These manures contain from ·75 to 1·0% of nitrogen and 2% of phosphoric acid, and are sold at from 20 to 25 P.T. per ton. These substances form a valuable substitute for farm-yard manure and are sold at a very reasonable price. A comparison of the analyses with those given of farm-yard manure will show the latter substance to be much inferior in composition. The annual production of the two preceding manures is about 4000 tons. The sweepings of certains towns are sold after sifting to the extent of about 2000 tons per year.

Various Products.

Other manures offered by this local company are as follows:—

Bone meal.—This is steamed and sold under a guarantee of 2% nitrogen, and 20% of phosphoric acid for 330 P.T. per ton.

Meat meal.—This manure is made from the refuse of the carcasses of animals, and from meat which is recognised as unfit for human consumption. It is sold on a basis of 9% of nitrogen at 500 P.T. per ton.

Dried blood.—Fresh blood contains 80% of water and from 2·5 to 3% of nitrogen. When dried it forms a very concentrated and nitrogenous manure, which has a ready sale in Europe where it is generally sold on a basis of 12%

nitrogen. The article in this country is guaranteed to contain 10% of nitrogen, and is offered at 600 P.T. per ton. It decomposes readily in the soil and must be looked upon as a valuable fertiliser. It is especially esteemed in horticulture, and is looked upon as very suitable for sugar-cane.

Powdered horn.—Horn is rich in nitrogen, though it is in a very insoluble state. It is sometimes ground to a very fine powder and composted with horse-manure or with lime before use, to help to break down the nitrogen it contains into simpler forms. This considerably increases its value. The percentage of nitrogen varies from 8 to 14%.

In France, what is known as "torrefied" horn is produced, that is horn which has been subjected to the action of steam. This is also manufactured in this country and sold under a guarantee of 12% nitrogen for 550 P.T. per ton.

Special manure.—This, consisting of a mixture of dried blood, meat meal, bone meal, is sold for 450 P.T. per ton, and contains 4 to 5% of nitrogen and 10 to 12% phosphoric acid.

It is interesting to compare the prices of these manures with the cost of a mixture of nitrate of soda and superphosphate of the same effective composition. If we assume for the sake of comparison that nitrate of soda containing 16% of nitrogen costs P.T. 1000 per ton and that superphosphate containing 17% of phosphoric acid costs P.T. 292½ per ton it will be seen that:—

1 unit *i. e.* 1%	per ton	of nitrogen costs...	...	62½ P.T.
1 „ *i. e.* 1%	„	„ phosphoric acid costs		17 „

Now the nitrogen in nitrate of soda and the phosphoric acid in superphosphate are both in their most available

forms, while in the refuse manures under consideration they exist in varying degrees of availability; it is therefore necessary to make allowance for this by considering 75% of the nitrogen in these manures to be available and 66% of the phosphoric acid. Thus we have in their case:—

1 unit of nitrogen worth ... ... $46\frac{1}{2}$ P.T.
1 .. phosphoric acid worth ... ... $11\frac{1}{2}$ ..

Making use of these figures we find that the value of these manures is as follows:—

	Composition per cent		Value of nitrogen	Value of phosphoric acid	Calculated value	Selling price
	Nitrogen	Phos. ac.	P.T.	P.T.	P.T.	P.T.
Matière Première premier choix...	1·5	1·75	70	20	90	60
Matière Première extra ...	1·75	2·5	82	29	111	75
Poudrette "best"	2·0	2·5	93	29	122	100
Poudrette "best best" ...	2·25	2·5	105	29	134	125
Engrais des Tanneries ...	1·2	2·0	56	23	79	25
Bone meal	2·0	20·0	93	230	323	330
Meat meal	9·0	10·0	418	115	533	500
Dried blood...	10·0	5·0	465	58	523	600

In the case of this last manure the nitrogen is practically equal to that in nitrate of soda so that its value works out to 625 P.T. per ton.

In practice it is frequently noticed that manures such as the above often produce much better results than might be expected from their chemical composition. This is very probably due to their exercising a stimulating effect on the soil bacteria which, as is well known, play an important part in rendering soil fertile. Besides this it must also be borne in mind that there will be a considerable amount of useful material left for a second crop and that in course of time all the nitrogen, and nearly all the phosphoric acid will become available.

Ostrich guano.—During the past two or three years this manure has been placed on the market by "La Société du Parc des Autruches de Matarieh," which owns about 1000 birds. Its average composition is as follows:—

COMPOSITION OF OSTRICH GUANO.

Nitrogen	1·50%
Phosphoric acid	1·60%
Potash	0·43%

The price at which it is sold is 100 P.T. per ton.

Bone black.—Small quantities of this phosphatic manure are placed on the market in Egypt. Bone black, or as it is sometimes called "Bone charcoal" or "Bone char," is produced in enormous quantities for employment in the process of sugar refining. When the bones are heated in a closed retort, instead of burning to white ashes as they would were there a free access of air, they undergo destructive distillation and the resulting product contains a considerable percentage (about 10%) of carbon. After

use in the sugar refineries, the bone black is renewed by being again subjected to heat, but as the process is repeated the percentage of carbon becomes reduced, and the material is too poor in this ingredient to effectively act as a filter. It is now "spent," and is technically known as "spent char," which in Europe is used for the manufacture of superphosphates. In Egypt this material is used in the raw state but as however only one refinery exists in the country, viz that at Hawamdieh, the total production is very limited.

Bat guano.—Small quantities of this material are found in rock crevices in Upper Egypt and are sometimes employed as manure. Its inaccessibility, however, renders it difficult and costly to procure. It varies greatly in composition, the nitrogen ranging from 1% to as much as 9% in exceptional cases.

ARTIFICIAL MANURES.

In the foregoing pages the substances discussed from the point of view of their manurial properties have been the ordinary residues of the farm from the feeding of animals, and those substances of manurial value natural to the country or produced in it frcm various industries. With the intensive agriculture now in vogue the supplies of these native manures are proving inadequate, and the necessity of intrcducing into the country certain plant foods in a highly concentrated form is every year becoming more and more pronounced.

There therefore still remain to be considered those materials, of a more or less artificial or manufactured character, which are beginning to be largely imported to supplement the local manures.

The chief "artificials," as they are commonly called, supply only one important plant food to the land and may conveniently be classified as:—

(*a*) Nitrogenous manures.
(*b*) Phosphatic ,,
(*c*) Potash ,,

In the following pages only the more important members of each class will be dealt with.

NITROGENOUS MANURES.

The two great nitrogenous manures of the present day are nitrate of soda and sulphate of ammonia, both of which are beginning to be extensively used in Egypt.

Nitrate of Soda.

This, in view of the immense quantities now employed in agriculture, must be regarded as the more important manure of the two.

Nature.—When perfectly pure, nitrate of soda (sodium nitrate, $NaNO_3$) is a white crystalline salt easily soluble in water, one part dissolving in about one part of water at ordinary temperatures. It crystallises without water of

crystallisation, but is always somewhat moist as it is slightly deliquescent. The commercial article is usually of a dirty white colour and is put on the market as 95% pure. This guarantee is sometimes expressed as "less than 5% Refraction," meaning that the impurities—chiefly moisture and common salt—do not exceed 5% of the whole.

Source.—The crude material from which the commercial article is prepared forms great deposits in certain desert districts in Peru, Chili, and Bolivia and goes by the name of "Caliche." It varies much in composition and may contain anything from 25 to 50 % of nitrate, the rest being earthy and stony matters along with certain salts, chiefly chlorides and sulphates of magnesium, calcium and sodium.

The deposit is always found comparatively near the surface, lying under a useless covering of gravel, clay, and gypsum, and may vary in thickness from a few inches to ten or twelve feet. Many of the deposits are at high altitudes (3000 to 4000 feet) and at considerable distances inland. Different theories have from time to time been put forward to explain the presence of these deposits. One is that they are residues from the decay of great masses of sea-weed: another, that they are accumulations of salts brought down from higher levels by rivers which have long ceased to exist.

Preparation.—The preparation of nitrate of soda from "Caliche" may be briefly summarised as follows. The deposit is exposed by blasting with gunpowder. The large masses are broken up and the material is passed into huge refineries where it is extracted with hot water, and

the resulting solution run out into great tanks to cool and crystallise. The nitrate crystals which form are removed, freed from the mother liquor by a slight washing and spread out in the sun to dry. The salt is then ready for putting into bags for shipment to the various markets of the world. The exportation of nitrate of soda from Chili began about the year 1830. In 1840 the quantity exported amounted to about 14,000 tons; by 1870 it had increased to about 200,000 tons; in 1880 it was 400,000 tons; during the season 1905-1906 it exceeded 1,500,000 tons.

The composition of the stuff as it leaves the works averages between 96 and 97 % nitrate with some 2 % water and traces of chlorides, sulphates and insoluble matters. Unless deliberately adulterated or allowed to get wet it seldom falls below the guaranteed 95 %. The only really harmful impurity likely to be found in the manure is perchlorate. Recent experiments go to show that nitrate containing more than a mere trace of this salt may do damage to crops to which it is applied, but the exact amount that must be present before any appreciable effect is produced is still a matter of doubt.

Character as a manure.—Nitrate of soda guaranteed 95 % pure contains rather more than $15\frac{1}{2}$ % nitrogen and is, next to sulphate of ammonia, the most concentrated form of nitrogen at present used as a manure. It is usually the cheapest form of nitrogen on the market, and its price is utilised in valuing the nitrogen of other manures.

The character of the salt, *i. e.* its ready solubility and the ease with which it diffuses in solution, together with

the fact that in it the nitrogen is in a form of combination capable of direct absorption into the plant, makes it an exceedingly active manure; in other words it is a manure giving an almost immediate return for its application. Its inability to form insoluble compounds with any of the constituents of soil renders it liable to be washed out of land by heavy rain or flooding, and this has to be borne in mind in its application. On the other hand, as it is not "fixed," as the expression is, it distributes itself rapidly throughout the soil layer, and is found to encourage the development of deep and well-spread roots. This is highly desirable as it not only increases the feeding area of the crop but makes it less likely to suffer from want of water on the drying up of the surface soil.

To avoid the risk of loss by drainage nitrate is usually applied as "top-dressing" and in comparatively small doses, and if a heavy application is wanted this is preferably put on in several small dressings rather than in a single large one.

To get the full value out of an application of nitrate the land must be well provided with phosphate and potash.

The salt is a useful manure for all crops except the leguminous group, which, being able to draw its nitrogen from the air, is not greatly benefited by the addition of nitrogenous manures.

The amount of nitrate which should be applied to land will depend upon the particular case in question but anything from one hundred to two hundred kilogs. per feddan may be given.

Too heavy applications tend to the development of stem and leaf at the expense of grain or root as the case may be, and with the cereals may bring about "laying."

In connection with the use of the manure it is to be noted that it should never be allowed to lie mixed with superphosphate for any length of time, as the latter always contains free acid which decomposes the nitrate with liberation of nitric acid. At ordinary temperatures this loss may be practically nothing, but if, through any cause, the temperature of the mass rises, the loss may become very considerable. If nitrate is to be applied with superphosphate it is therefore better to apply the manures separately, or at any rate to mix them only immediately before use. Again it is not advisable to allow nitrate to lie in contact with any highly organic mass like farmyard manure, as under these conditions reduction of the nitrate may take place with the escape of free nitrogen to the air.

The following facts are of interest in view of the place nitrate of soda is now taking in Egyptian agriculture.

In the year 1904 about 2500 tons were imported into Egypt; in 1905 this increased to 5000 tons, in 1906 some 11,000 tons were imported and in 1907, 20,000. In 1904 the average price per ton was 1000 P.T., in 1905 1025 P.T., and in 1906 nearly 1,100 P.T. Up till 1905 practically all the nitrate of soda imported was applied to the wheat and cotton crops, wheat taking about 90 per cent. of the consumption. In 1906 some 500 tons were applied to the maize crop.

SULPHATE OF AMMONIA.

This manure is a waste product from certain industries in the working of which nitrogenous organic matters, or mineral matters containing a certain amount of nitrogenous organic matter, are subjected to destructive distillation. It therefore merits the name "artificial" to a greater extent than nitrate of soda which, as has just been shown, is a purified natural deposit.

Nature.—Sulphate of ammonia or more correctly ammonium sulphate [$(NH_4)_2 SO_4$], when pure, is a white crystalline salt without water of crystallisation. It is very soluble though not quite so soluble as nitrate of soda, one part dissolving in two parts cf water at ordinary temperatures. The commercial article is usually somewhat coloured, the colour varying with the nature and amount of impurity, but most samples have a greyish appearance. The pure salt contains 25·75% ammonia, equal to 21·21% nitrogen. Commercial sulphate averages about 24½% ammonia, equal to 20·2% nitrogen. The pure salt is completely volatilised on heating, so adulteration of the stuff by admixture with any non-volatile salt or substance is easily detected. As a general rule the only impurities likely to be present are moisture, free sulphuric acid and perhaps a little insoluble matter. Formerly ammonium thiocyanate (sulphccyanide) was occasicnally met with but sulphate as now prepared rarely contains even a trace of this impurity. As thiocyanate is exceedingly injurious to plant life its presence is highly objectionable. It is easily detected, however, by the addition of a few drops

of ferric chloride solution to a solution of the sulphate, when even a trace of thiocyanate imparts a blood-red colour to the mixture.

Preparation.—When organic matters containing nitrogen are heated in the absence of air a proportion of the nitrogen comes off in the form of ammonia gas, and this when combined with sulphuric acid yields ammonium sulphate. The great source of ammonium compounds is coal. Ordinary coal contains from 1 to $1\frac{1}{2}\%$ of nitrogen, and in the distillation of this in the preparation of coal gas and coke a certain amount of ammonia is produced and caught in what is known as the "ammoniacal liquor of the gas-works."

On mixing this strongly alkaline liquid with lime and redistilling it all the ammonia comes off. It is passed into sulphuric acid where it forms sulphate of ammonia which crystallises out on concentration of the solution.

The salt is also produced in the preparation of paraffin oil and paraffin wax from bituminous shale, (a kind of hardened mud containing organic matter), and to a less extent from the waste gases of iron works and from the distillation of bones in the preparation of animal charcoal for sugar refining and other purposes.

Details of the world's production of sulphate of ammonia are not available, but in 1905 some 270,000 tons were produced in Great Britain. The price per ton fluctuates between fairly wide margins but the average price during 1905 was 1250 P.T. During 1906 some 700 tons were imported into Egypt for application to the maize and cotton crops and in 1907, 1100 tons.

The salt as a manure.—Sulphate of ammonia is the most concentrated nitrogenous manure on the market. Compared with nitrate of soda it is not so rapid in its action, chiefly for the reason that before it is available for the plant it must undergo nitrification, which in well aerated soils it very soon does under the influence of the nitrifying bacteria. As ammonia can be "fixed" by various of the soil constituents nitrogen in this form is not so liable to be washed out the of soil as in the form of nitrate. Of course after nitrification this no longer holds true. Land to which sulphate is applied should be well provided with lime, preferably as carbonate, as this serves the double purpose of aiding nitrification and of combining with the sulphuric acid set free on the decomposition of the sulphate. As with nitrate of soda, the salt to give the best results should be well supported in the soil by the presence of good supplies of phosphate and potash. It can safely be mixed with superphosphate, but care must be taken to avoid mixing it with any basic substance such as lime or basic slag as these readily drive off its ammonia. As this takes place at ordinary temperatures the loss from such mixing is much more serious than any likely to occur from mixing nitrate and superphosphate.

Sulphate of ammonia like nitrate of soda may be applied with advantage to practically all except leguminous crops. According to circumstances the quantity used will vary from 75 to 150 kilograms per feddan. Its nitrogen not being immediately available it should be put on the land a little before it is required by the crop so as to allow it time for nitrification.

NEW NITROGENOUS MANURES.

A recent estimate puts the exhaustion of the nitrate beds of South America at some 25 to 30 years from the present. In view of this, and of the fact that the output of a bye-product like sulphate of ammonia must always be necessarily limited, the question of new nitrogenous artificials is becoming of first importance.

Within the last few years two such manures have been successfully produced and put on the market and are beginning to be known to the agriculturist.

These are "nitrate of lime" made in Norway, and "lime nitrogen" or "nitrogen lime" an impure form of the compound calcium cyanamide—$CaCN_2$—made in Germany and Italy. Both manures derive their nitrogen from the atmosphere but can only be produced where water power is plentiful, as cheap electricity is essential to their profitable manufacture.

Nitrate of Lime.

In the preparation of this substance a current of air is passed through a specially constructed electric furnace and a certain amount of combination of the nitrogen and oxygen takes place with the formation of the gas nitric oxide—NO. This nitric oxide which forms about 1 % of the air leaving the furnace is made to unite with more oxygen and with water forming a mixture of nitrous and nitric acids which by treatment with milk of lime gives a mixture of the calcium salts of these acids. The calcium nitrite in the mixture is converted into nitrate by means of nitric acid (of previous manufacture) and the solution

is concentrated until it solidifies. The mass thus obtained contains some 13 % nitrogen equal to 75 % nitrate of calcium—$Ca(NO_3)_2$. It is highly deliquescent which necessitates the use of air-tight drums in its transport. For agricultural purposes it is usually converted into a basic nitrate by the introduction of excess of lime, as in this form it is less difficult to deal with.

As a manure it is of equal value to nitrate of soda, equal amounts of nitrogen being considered.

Lime Nitrogen or Nitrogen Lime.

This is a fine dark dusty powder, rather like basic slag in appearance but smelling of acetylene, especially when moistened. It contains approximately 55 to 60 % of the compound $CaCN_2$, calcium cyanamide, equal to some 20 % nitrogen, and is therefore a manure of about the same nitrogen content as sulphate of ammonia.

In its preparation calcium carbide—$Ca\,C_2$—is first formed by heating together chalk and coke in an electric furnace. The carbide is then coarsely powdered and heated in a kind of gas retort and nitrogen is passed over it. Combination takes place with the formation of calcium cyanamide. The nitrogen is obtained from air, the oxygen being removed by passing the air over red-hot copper. The copper oxide formed is reduced to the metallic state again by heating in coal-gas.

In contact with water, calcium cyanamide decomposes slowly at ordinary temperatures giving rise to calcium carbonate and ammonia and this change is what takes place in the soil, aided probably by some bacterial action.

The manure should be harrowed into the surface soil to avoid loss of ammonia and it should be applied to the land a week or two before sowing to allow time for decomposition. When applied with the seed it interferes with germination. It should never be mixed with superphosphate or other acid manure as this results in the production of harmful compounds.

Various experiments have been made with this new manure which point to its being nearly, if not quite, equal in value to sulphate of ammonia.

The manure must be kept dry to avoid loss. Even moist air affects it with the liberation of dangerous inflammable gases. As in the case of nitrate of lime it is therefore advisable to use air-tight drums for its transport.

PHOSPHATIC MANURES.

Of the substances used to supply phosphoric acid to the soil, ground bones and the soluble manures derived from them by treatment with sulphuric acid are among the oldest and best known. In Egypt, however, bones are almost entirely employed in the preparation of animal charcoal for the sugar refineries, and the phosphatic manures at present of interest to the Egyptian agriculturist may be limited to:—

(*a*) Raw or mineral phosphate;
(*b*) Mineral superphosphate;
(*c*) Basic slag.

Raw phosphate is only occasionally applied to land in Egypt, but it is interesting as the substance from which

mineral superphosphates are manufactured and in view of the fact that phosphatic deposits have been discovered in various parts of the country, notably at Keneh, in the neighbourhood of the Dakhla Oasis, and in the Sinai Peninsula.

Apart from raw phosphate mineral superphosphate is the only phosphatic artificial at present employed in any quantity in the country and its use is steadily increasing. Its nature and manufacture must therefore be considered at some length.

Basic slag may come into more general use in time; so far its application has been practically confined to small experimental areas.

Raw Phosphates.

In various parts of the world rocky masses exist which on analysis prove to be largely made up of tricalcic orthophosphate – $Ca_3(PO_4)_2$. The best known deposits are those of the United States (South Carolina and Florida) Canada, France, Belgium, Algeria, etc. etc. These deposits, either in a finely divided state or after conversion into the manure "superphosphate," to be described later, are now employed in immense quantity in agriculture to replace the phosphoric acid removed from the land in crops and so keep up the percentage of this valuable plant food in the soil. The different deposits, some of which show distinct signs of animal origin, vary very much amongst themselves both as regards physical character and chemical composition. Some are of a hard crystalline nature making them difficult to grind, others are soft and amor-

phous and can easily be reduced to fine powder. Some occur in great rock masses, others as comparatively small nodules mixed with useless earthy matters. Some contain 70, 80 or even as much as 90 % tricalcic phosphate *e.g.* Canadian and Florida phosphates, others have only some 30 to 40 % *e.g.* Belgian. In colour they differ but when ground most of them have a yellowish brown appearance.

The chief impurities present in the natural phosphates are silica and silicates, carbonate fluoride and chloride of calcium, and compounds of iron and aluminium chiefly oxide and phosphate. The value of a deposit for the making of superphosphate is determined partly by its richness in phosphate, and partly and to a considerable extent by the nature of the impurity present. The ease with which it can be reduced to powder is also a consideration. Closely related to the above phosphatic rocks are the phosphatic guanos. These deposits, found chiefly on islands in the Pacific and in the West Indies, are derived from the bodies and excrements of sea birds and may contain from 60 to 80 % phosphate of lime. They are similar in their origin to the nitrogenous guanos but their organic matter has almost entirely disappeared, and through the action of water they have lost all the soluble substances they once contained.

In the Egyptian deposits the presence of fish teeth, fragments of bone, etc. points to their being derived from great accumulations of fish remains. The different layers vary considerably in the amounts of phosphate they contain but 40 to 50 % may be taken as a fair average. The stuff is of too low grade for profitable exportation but in

view of the price of imported phosphatic manures it must be regarded as a valuable addition to the list of native manures and there is no reason why the application of the finely ground deposit should not become much more general than it is. From its sparing solubility in soil water ground phosphate is naturally slow of action, and the effect of its application is spread over several years. Fine grinding, by greatly increasing the amount of surface exposed to the soil solvents, greatly increases the availability of the manure. The consumption of this native mineral phosphate amounts probably to about 2000 tons per annum.

Mineral Superphosphates.

The name superphosphate (usually contracted to "super") is applied to the mixture resulting from the regulated action of strong sulphuric acid upon some form of tricalcic orthophosphate and consisting essentially of monocalcic orthophosphate and calcium sulphate (gypsum). Supers were originally made by treating spent animal charcoal with acid, but now the phosphate employed is nearly always that of ground mineral phosphate or phosphatic guano. In the manufacture of some high-class supers this is replaced by that of bone-ash. The "dissolved bones" and "vitriolated bones" of the artificial manure market are simply varieties of super prepared from bones and acid, containing varying quantities of nitrogen derived from the organic part of the bones, and therefore of additional value from the presence in them of this constituent.

The object in making superphosphate is to produce a

manure containing its phosphoric acid in a readily available form. Tricalcic phosphate is practically insoluble in water and only sparingly soluble in solutions of carbonic acid gas ; of such solutions the water of the soil may be taken as a special case. By treatment with sulphuric acid the phosphate – $Ca_3(PO_4)_2$ – is converted into monocalcic phosphate – $CaH_4(PO_4)_2$ – which is easily soluble in water.

Briefly stated the steps in the manufacture of superphosphate are as follows. The raw phosphate is first reduced to powder by grinding. It is then mixed in special vessels with a calculated amount of "chamber" sulphuric acid and the pasty mass resulting is run into "pits" or "dens" to "set." This setting or drying is brought about largely through the union of the calcium sulphate with water forming gypsum as in the setting of plaster of Paris. When it is complete the mass is dug into, broken up, pulverised in a suitable mill and put into bags for the market.

The quantity of acid used is regulated by the nature and the amount of the impurity present in the phosphate. Carbonates, chlorides and fluorides and the oxides of iron and aluminium are more objectionable impurities than silica and many of the silicates. They use up acid which should go to attack phosphate, and so add to the expense of manufacture, which silica and the more insoluble silicates do not do. It is of course evident that, apart from the nature of the impurity, the more tricalcic phosphate there is present, the greater the amount of acid required to convert it into monocalcic phosphate. A further objection

to the presence of iron and aluminium compounds in the phosphate will be brought forward immediately in dealing with the question of the reversion of the soluble phosphate of supers. The skill of the maufacturer lies in turning out, from the raw phosphate at his disposal, a manure containing as much soluble phosphate as possible and at the same time of a fine earthy texture, easy to handle and apply. More acid may give a little more soluble phosphate but if the manure becomes a sticky paste in consequence the difficulty in dealing with it far outweighs the benefit derived from the increased solubility.

Superphosphates are therefore manures containing primarily monocalcic phosphate and gypsum, with some tricalcic phosphate, sandy matters and usually small quantities of sulphates and phosphates of iron and aluminium.

They are divided into low, medium and high-class supers according to the percentage of soluble phosphate they contain. In the purchase of superphosphate, especially when large quantities are in question, a guarantee of composition should be given by the seller. In such a guarantee the percentage of soluble phosphoric acid is usually expressed thus:—

Soluble phosphoric acid – $P_2O_5 = 13{\cdot}5\ \%$, equal to

Soluble phosphate of lime – $Ca_3\ (PO_4)_2 = 29{\cdot}4\ \%$

although the acid is present in the manure as monocalcic and not as tricalcic phosphate. This really means that in this particular sample the amount of soluble monocalcic phosphate—$CaH_4\ (PO_4)_2$—is equal to what would be formed by the conversion of $29{\cdot}4\ \%$ of insoluble tricalcic phosphate into the soluble form.

Low class supers contain less than 25 % soluble phosphate expressed as tricalcic phosphate. Medium have between 25 and 30 % and high class have from 30 % upwards. The highest class of supers containing up to 45 % are usually prepared from bone ash and acid.

All supers contain some insoluble phosphate. This is chiefly $Ca_3(PO_4)_2$ and runs from 1 to 4 %. As a general rule the amount of this ingredient is not taken into account in valuing the manure.

Reversion in supers.—Supers after standing for some time usually show a fall-off in the percentage of soluble phosphate they contain. They are said to have "reverted" to some extent or gone back to the insoluble state. This reversion may be the result of one or other or both of the following reactions taking place in the mass.

Either the monocalcic phosphate has interacted with the small quantity of tricalcic phosphate present forming insoluble dicalcic phosphate – $Ca_2H_2(PO_4)_2$ – or it has been acted upon by the sulphates of iron and aluminium present giving rise to the insoluble phosphates of these metals – $FePO_4$ and $AlPO_4$. Reversion from the second cause is more objectionable than that from the first as the phosphates formed are of a more insoluble nature. The insoluble phosphate resulting from reversion is however of more value than original insoluble phosphate. In the first place it is in a very much finer state of division and is more easily rendered available; secondly, dicalcic phosphate is more soluble in soil water than tricalcic is.

Superphosphate as a manure.—When super has been applied to land the first water which comes into contact

with it rapidly dissolves, among other things, the soluble monocalcic phosphate and carries it down into the soil layer where it immediately undergoes what may be called an extensive reversion. In other words it meets various compounds of calcium, iron and aluminium and reacts with them forming compounds which are only very sparingly soluble in soil water. There is therefore little chance of phosphate being washed out of land and lost in drainage, which fact is usually expressed by saying that the fixation of soluble phosphate in soil is very complete. At first glance it would appear as if, with the return of the phosphate to the insoluble state, the labour of the manufacturer had been thrown away, but it must be remembered that although again practically insoluble in pure water, the phosphate is now spread in a very fine state of division over the surfaces of an enormous number of soil particles. It has therefore a much better chance of being acted upon by the soil water and rendered available than in its former state of solid particles however finely ground. Again the mixing with the soil particles is much more intimate than could ever be attained by sowing ground phosphate on land and working it in.

Superphosphate is a useful manure for practically all crops, its application being particularly beneficial in the case of roots, where rapid early growth is desirable. It is best employed on land fairly well supplied with lime on account of its acid character. With soils poor in lime, ground phosphate or basic slag is to be preferred. The quantity applied is usually about two hundred kilograms per feddan.

The action of the manure is naturally most marked in the year of application but is not by any means confined to this year.

During 1906 from 1500 to 2000 tons were imported into Egypt costing from 280 to 320 P.T. per ton, with a guarantee of from 16 to 18 per cent. of phosphoric acid soluble in citrate solution. It is applied chiefly to the cotton crop. The same amount was imported during 1907.

Basic Slag.

The heavy grey-black powder sold under this name is a manure of only some twenty years' standing and is a bye-product in the preparation of steel by the Bessemer process from pig-irons rich in phosphorus. During the process this phosphorus is oxidised and enters into combination with the lime and magnesia of the basic lining of the vessel in which the operations are conducted forming a slag. At one time this was thrown on the rubbish heap as useless; it is now very finely ground and in this state forms one of the cheapest and most important of phosphatic manures on the market. The composition of basic slag naturally varies considerably. Its main ingredients are lime – CaO – and phosphoric acid – P_2O_5. The CaO is present as free lime and combined with the P_2O_5 as tetracalcic orthophosphate – $Ca_4P_2O_9 = 4\,CaO,\ P_2O_5$ – with considerable quantities of the oxides of iron and magnesium, some silica as silicate and a little sulphide. The amount of phosphoric acid – P_2O_5 – may be anything from 10 to 20% so the manure should always be bought on

an analysis, which should also indicate the fineness of grinding. This ought always to be such that at least 80% of the sample passes through a sieve of 10,000 meshes to the square inch, *i. e.* about 1500 meshes per square centimetre, as the availability of the manure is greatly influenced by its state of division.

Tetracalcic phosphate is a more soluble substance than tricalcic phosphate for, although both are practically insoluble in pure water, the former readily dissolves in certain solutions in which the latter does not, *e.g.* in solutions of ammonium citrate and to a less degree in carbon dioxide solutions. Basic slag is therefore a more rapid manure than ground mineral phosphate, both being applied in the same degree of fineness.

On account of its basic character it is best suited for land high in organic matter and low in lime. When applied with soluble nitrogen this latter should be in the form of nitrate as the free lime of slag rapidly drives off ammonia from ammonium sulphate. This free lime and also the oxide of iron present have also the effect of causing a large reversion of soluble phosphate if by any chance the powder is mixed with super. From its nature, basic slag is a manure the effect of which extends over several years. Applications run from one hundred and fifty to three hundred kilograms per feddan.

Basic slag has till now been used only to a limited extent in Egypt. It costs from 250 P.T. to 300 P.T. per ton according to quality.

POTASH MANURES.

The soil of Egypt being particularly rich in potash, the application of this plant food to land is seldom considered necessary, and accordingly potash manures are only of secondary interest to the Egyptian agriculturist.

At the present day the world's supply of potash manures comes from the great salt deposits of central Europe, the principal mines being those of the Stassfurt deposit near the Hartz mountains in Germany. These deposits, made up of layers of different compositions, are in many cases of great thickness and appear to have resulted from the drying-up of inland seas. Anhydrite and gypsum (forms of $CaSO_4$) and rock salt ($NaCl$) compose by far the greater part of the mass and it was for this last that the Stassfurt mines were originally worked. The great commercial value of the deposits now rests on the presence in them of certain comparatively thin layers of salts of potassium and magnesium, the principal one consisting of carnallit, a double chloride of these two metals. It is from these layers that practically all potassium compounds are now derived, whether for use in agriculture or in the arts.

The chief potash manures are :

(*a*) Kainit.

(*b*) Calcined double sulphate.

(*c*) Muriate of potash.

Kainit.

This is the most widely used potash manure, and is simply the natural layer crushed. It consists of sulphates and chlorides of potassium and magnesium and always contains considerable quantities of rock salt (30-40 %). Its composition varies somewhat but as a rule the potash — K_2O — averages 12 ½, equal to some 23 % sulphate, in which form it is largely present.

Calcined Double Sulphate.

By a rather complicated process there can be prepared from kainit a double sulphate of potassium and magnesium with water of crystallisation. On heating this salt a portion of the water goes off and the remaining mass contains on the average 26 % potash, equal to 48 % sulphate. This is an important potash manure which may be regarded as a kind of concentrated kainit.

Muriate (or Chloride) of Potash.

This salt is prepared from the natural layer carnallit and contains fully 50 % potash, equal to some 80 % chloride. It is employed as a manure to a considerable extent, as in cases where questions of transport arise, its high potash content gives it an advantage over the two manures just referred to.

Generally speaking however, it is better to apply potash to land in the form of sulphate rather than as chloride, as many crops do not appear to do well in the presence of the latter salt. For one thing the chloride, though a more

soluble and diffusible compound, is apt through double decomposition to form objectionable salts in the soil, such as calcium chloride.

Potash manures pay best on light sandy or calcareous soil and the crops to which they are applied with greatest advantage are potatoes and the leguminous crops.

Being a plant food which is well "fixed" in soil through interaction with certain silicates, etc. there is little fear of loss of potash through drainage. Potash manures therefore do not in their application demand the careful handling necessary in dealing with the soluble nitrogenous manures.

As regards the quantity to be employed, this among other things will depend on the kind of manure used and varies from one hundred and fifty to two hundred and fifty kilogs. in the case of the poorer salt, kainit, to from fifty to eighty kilogs. per feddan in the case of the stronger manures.

During 1906 only some fifty tons of sulphate of potash were imported into Egypt at a cost of 950 P.T. per ton.

GLOSSARY OF ARABIC TERMS.

ard	soil.
asfar	yellow.
badala	watering implement.
baitana.	implement for dividing land into beds.
boos	reeds (Phragmites communis); also stalks of maize etc.
coufri	ruins of mud brick buildings used as manure.
dineba	Panicum crus-galli.
durah	collective name for maize & sorghum.
erd asfar	yellow soil *i.e.* sand.
erd iswid	black soil *i.e* clay.
enlla	Sinapis Arvensis (wild mustard).
fass	hand-hoe.
fassing	act of using a fass.
henna	Lawsonia alba.
hod	large basin *i.e.* tract of land surrounded by a dyke for flooding
hoshay.	enclosed area frequently a division of a hod.
kabar.	Sinapis nigra.
kassabia	native implement for levelling dry land.
kism	division.
lowatt	implement for levelling land under water.
lubain	Sonchus spp.
mangal	sickle for harvesting wheat and barley.
norag	implement for thrashing cereals.
mazaka	hand-hoe.
minshar	hand-hoe.
mintena	Chenopodium.
nattala.	swing basket for raising water.
neguil	Cynodon dactylon.
noria	water lift.
ramroom	implement for covering seed in basin irrigation lands.
rigla	Portulaca oleracea.
sakieh	Persian wheel.
samar	Cyperus alopecuroides.
seback	manure.
shadoof	water lift.
sharshara	similar to minshar.
taboot	water wheel.
tafla.	efflorescence of salt in heavy land in rainless region.
tamboor	Archimedean screw.
tara	wheel of "taboot".
tech-beech . . .	applying manure to individual plants.
waboor.	engine.
yanni	Archimedean screw.
zahafa	plank of wood for breaking clods.

INDEX.